ABSTRACT

Title of Document: ASSESSMENT OF NITROGEN STATUS AND VEGETATION COMPOSITION IN TIDAL FRESHWATER MARSHES USING PARTIAL LEAST SQUARES REGRESSION MODELS OF HYPERSPECTRAL CANOPY REFLECTANCE

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Hyperspectral canopy reflectance was used to predict sub-surface water nutrients, vegetation composition, and canopy nutrients, which could lead to more useful means for assessing the status of wetlands. Thirty field quadrats at two tidal freshwater marsh sites on the Nanticoke River (Maryland) were treated with five nitrogen levels. During the 2004-05 growing seasons, hyperspectral canopy reflectance was measured using a spectroradiometer with 1nm resolution across the visible and near – infrared spectrum (350-1075 nm), water samples were collected using lysimeters, species cover was quantified, and biomass was collected and analyzed for canopy nutrients. ANOVA was used to determine whether nitrogen affected reflectance, species composition, canopy N and P, and partial least squares regression was used to develop reflectance models predictive of these ecosystem properties. Results indicated that hyperspectral radiometry could be used as a remote sensing tool for quantifying sub-surface water nitrogen, vegetation composition, and canopy nutrients in tidal freshwater marshes.

# ASSESSMENT OF NITROGEN STATUS AND VEGETATION COMPOSITION IN TIDAL FRESHWATER MARSHES USING PARTIAL LEAST SQUARES REGRESSION MODELS OF HYPERSPECTRAL CANOPY REFLECTANCE

By

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# Dedication

To Conrad and Alec, who, from the beginning, cheerfully accompanied me every step of the way,

To Dick Leinenkugel, who was there when I was both overwhelmed and overjoyed,

and to Mike, who always listened.

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# Chapter 1: Introduction

## *1.1 Problem definition*

Tidal freshwater wetlands are unique ecosystems, important to the world for a variety of reasons. They are used for recreational purposes, commercial fisheries, and are rich in biodiversity. For example, more bird species inhabit tidal freshwater marshes than any other type of marsh (Mitsch and Gosselink 2000). Functional values of wetlands include stabilizing the water supply throughout floods and droughts, protecting the shorelines, recharging the groundwater, and cleansing polluted waters (Mitsch and Gosselink 2000). Wetlands behave as a filter between land and water bodies (Zhang et al., 1997), removing sediments, nutrients, and organic pollutants from the water source, thereby improving the quality of the water before it reaches the water body (Krieger 2003; Poe et al., 2003).

Unfortunately, coastal marshes are one of the ecosystems often subject to continual exploitation, modification, and destruction (Zhang et al., 1997; Rosso et al., 2005). Tidal freshwater marshes, due to their inland coastal position, are at a high risk to be affected by human interactions, such as soil erosion from construction sites and croplands, discharge from waste treatment plants, and agricultural runoff (Kahn and Kemp 1985; Mitsch and Gosselink 2000). Nutrient non-point source pollution from agricultural runoff is an especially large, well-known problem. Agricultural crops use only 40-60% of their applied nitrogen fertilizer (Poe et al., 2003), allowing large

amounts of nitrogen to enter bodies of water, especially wetlands since they are usually located on the border between land and either lakes or rivers.

Over the last few years, the awareness of the importance of wetlands has increased and laws and regulations have been established to protect and restore wetlands (Mitsch and Gosselink 2000). Under the Clean Water Act, states must monitor wetlands regularly to ensure the water quality standards are met (USEPA 2002). Currently, the methods used to monitor nutrients in a wetland are labor-intensive and time-consuming (Rosso et al., 2005). An alternative method, therefore, such as remote sensing, is needed that can quickly and accurately quantify nitrogen and other nutrients in large areas of wetlands to detect ecosystem stressors, predict habitat changes, and monitor invasive species (Tiner 2004; Maheu-Giroux et al., 2005; Rosso et al., 2005; Salem et al., 2005).

### *1.2 Literature Review*

*Marsh response to nitrogen*

Nitrogen from agricultural runoff, wastewater treatment facilities, and other sources is known to cause eutrophication in open-water aquatic systems, stimulating algal blooms and causing a loss of submerged aquatic vegetation, a decrease in fish populations, and a decline in biodiversity (Mitsch and Gosselink 1993; Rabalais 2002). Fortunately, wetlands are capable of filtering nitrogen from water sources and releasing it as nitrogen gas through denitrification before nitrogen reaches open aquatic systems (Buscot and Varma 2005; Philippot and Germon 2005).

As nitrogen enters the wetland as urea, $(NH_2)_2CO$, it is rapidly transformed to ammonia and carbon dioxide with the catalyst enzyme, urease (Payne 1981; Thoren et al., 2004). While carbon dioxide is released to the atmosphere, ammonia is converted by autotrophic microorganisms, such as *Nitrosomonas* and *Nitrobacter*, to nitrate through nitrification. Nitrate, a soluble compound, can be taken up by plants, but can also be easily leached out of the soil and pollute nearby water bodies, unless wetlands perform denitrification, a four-step anaerobic process controlled by microorganisms, which changes nitrate into dinitrogen gas (Philippot and Germon 2005).

*Remote sensing in marshes*

At the Earth's surface, solar energy is reflected, absorbed, or transmitted from all materials (Larcher 2003). The ratio of reflected energy to the total energy as a function of wavelength is called hyperspectral reflectance and can be measured with a spectroradiometer, which reports the spectral reflectance in hundreds of narrow (1 to 10 nm) and contiguous wavelength bands (Shippert 2004).

Hyperspectral reflectance, as well as other remote sensing techniques, can be used to extract biophysical information about a vegetation canopy from the interaction between solar irradiance and the canopy (Hurcom et al., 1996). In plants, chlorophyll and other leaf pigments are responsible for leaf energy absorption and reflection; low concentrations of chlorophyll result in less energy absorption and

more reflectance. Since chlorophyll concentrations are affected by nutrients, like nitrogen and phosphorus, hyperspectral reflectance can be used to indirectly quantify the availability of nutrients.

Some of the earliest work to quantify nitrogen concentrations in marshes through remote sensing was established by Tilley et al. (2003), where relationships between water column ammonia and reflectance indices were discovered. In 2005, Becker et al. discovered a correlation between eight hyperspectral bands and vegetation characteristics within freshwater marshes and Phillips et al. (2005) found spectral differences between vegetation communities in freshwater marshes using GIS remote sensing. Analysis for both vegetation studies was performed on vegetation data collected in August and early September, during peak biomass (Becker et al., 2005; Phillips et al., 2005). Vegetation changes in a coastal saltwater marsh were successfully mapped using digital airborne remote sensing (Thomson et al., 2004), as were *P. australis* communities in linear wetland corridors using color aerial photography imaging (Maheu-Giroux et al., 2005). The US Fish and Wildlife Service have also used remote sensing techniques to monitor wetland trends (Tiner 2004).

Besides nutrient and vegetation trends, remote sensing has also been proven to detect environmental stressors in wetlands. Oil spills in freshwater wetlands were identified using hyperspectral imagery (Salem et al., 2005), and significant differences between treatments of heavy metals and oil were found in wetland plants using hyperspectral reflectance (Rosso et al., 2005). The alterations in the plant's biochemistry and

cellular composition from environmental stressors produce measurable changes in reflectance (Rosso et al., 2005). For example, plants exposed to heavy metals exhibited a darker canopy and therefore a lower reflectance, than healthy plants (Schuerger et al., 2003; Wilson et al., 2004).

Other applications involving hyperspectral reflectance measurements include classifying the trophic status of lakes (Koponen et al., 2002), determining coral reef community structures (Hochberg et al., 2003), evaluating nitrogen concentrations in the wetland crop, rice (Xue et al., 2004), assessing wetland plant stress due to flooding (Anderson and Perry 1996), and correlating leaf nitrogen concentration to canopy hyperspectral reflectance in a forest (Smith et al., 2003; Townsend et al., 2003). Hyperspectral reflectance has also correctly identified moss species in Antarctica (Lovelock and Robinson 2002) and salt-water vegetation species in coastal wetlands (Silvestri et al., 2003).

Several studies relating hyperspectral reflectance to the identification of species at the canopy level have been performed on agricultural crops to investigate and improve the area of precision agriculture. Studies have shown high accuracy (up to 80%) in distinguishing soybean crops from weeds, such as the cocklebur (*Xanthium strumarium*) (Henry et al., 2004), sicklepod (*Cassia obtusifolia*) (Chang et al., 2004), and morningglory (*Ipomoea Iacunosa*) (Koger et al., 2004).

*Partial Least Squares Regression*

In order to correlate biological responses to reflectance data, partial least squares (PLS) regression has been used to develop predictive models of biological responses using full-spectrum data. PLS regression is an eigenvector analysis that reduces the full-spectrum data (independent matrix, X) to a smaller set of independent latent factors (i.e., PLS-components) with the dependent variable (biological responses) used directly during the spectral decomposition process. PLS uses the factors to predict responses in a population (Esbensen 2002; Smith et al., 2002).

Two data sets, called the training set and test set, are used to compute the model parameters in a PLS regression. The training set establishes the multivariate model for (X,Y) then predicts the Y matrix from the X as previously described. The test set is a new set of data that is used to test the model under realistic conditions in a process called test set validation. Since two data sets cannot always be obtained for validation purposes, another validation method, called cross-validation, can also be used (Petisco et al., 2005). In cross validation each biological response and spectra are iteratively excluded and a prediction of the sample value is made based on an equation developed with the remaining samples. The process is repeated until every sample has been left out once. The prediction residuals are combined to compute the validation equation statistics and RMSEP (Smith et al., 2003).

Martens uncertainty test eliminates useless predictors in a multivariate calibration. The test is based on the standard deviation of regression coefficients computed from values in the cross validation process. If the regression coefficient contains the value zero at the 95% confidence interval, it is eliminated from the model (Forina et al., 2004).

*PLS and hyperspectral reflectance*

PLS has become a useful method of analyzing spectral information. Petisco et al. (2005) and Smith et al. (2002) used PLS to develop predictive models of leaf nitrogen concentrations from near-infrared spectroscopy (NIRS) and hyperspectral remote sensing. A PLS regression model has predicted the LAI, chlorophyll and leaf nitrogen concentrations from reflectance data (Filella et al., 1995; Casa and Jones 2003; Zhang et al., 2003, Fridgen and Varco 2004). PLS has also been used to successfully predict and interpret heavy metal stress in wetland plants (Wilson et al., 2004), nitrogen concentrations in wheat (Hansen and Schjoerring 2003), and species composition and structure in grasslands (Schmidtlein and Sassin 2004).

*Reflectance indices*

Researchers have often used individual reflectance bands, ratios, or indices to relate hyperspectral data to biological and ecological properties. One of the most common reflectance bands used for analysis is the red edge (RE), defined as the wavelength of maximum slope at the red-NIR transition. The RE increases with higher chlorophyll content and is therefore generally responsive to changes in nitrogen and other nutrient

levels (Smith et al., 2003). To reduce data noise, a sensitive waveband is normalized by a non-sensitive waveband to form a ratio, such as a blue to red reflectance ratio ($R_{415}/R_{710}$). Other popular ratios for data analysis include the blue to red ratio ($R_{493}/R_{678}$), and the green to red ratio ($R_{564}/R_{768}$). Reflectance indices, or combinations of reflectance bands, used to relate spectral data to biological and ecological properties include the normalized difference vegetation index (NDVI= $(R_{nir}-R_{red})/(R_{nir}+R_{red})$) and photochemical reflectance index (PRI= $(R_{531}-R_{570})/(R_{531}+R_{570})$).

Spectral indices like the NDVI can accurately predict LAI of crops with a coefficient of determination as high as 0.95 (Hansen and Schjoerring 2003; Haboudane et al., 2004). Other agricultural crop studies have correlated LAI to a specific wavelength, such as green, $R_{560}$, or a simple ratio of spectral bands like $R_{810}/R_{560}$ (Xue et al., 2004).

Simple reflectance ratios have also been used to link reflectance measurements to nutrient concentrations. Tilley et al. (2003) showed that a reflectance ratio ($R_{493}/R_{678}$) explained 54% of ammonia concentrations in wetland water columns. A blue to red ratio ($R_{415}/R_{710}$) used by Read et al. (2002) strongly indicated leaf nitrogen in cotton (*Gossypium hirsutum*), and ratios of the near-infrared (NIR) to the visible (VIS) linked canopy nitrogen to fertilization rate in corn (*Zea mays*) (Diker and Bausch 2003). Other reflectance indicators of nitrogen include a higher reflectance curve in the NIR for fertilized plants (Tilley et al., 2004; Xue et al., 2004), and a correlation

between nitrogen and NDVI (Li et al., 2001, Bronson et al., 2005). The PRI and red-edge were both able to detect nitrogen ammonia levels in plants in research conducted by Strachan et al. (2002) and Tilley et al. (2003). Others, including Carter and Miller (1994), Tarpley et al. (2000), and Fridgen and Varco (2004) have used the RE as an indicator of chlorophyll in the plant, which is indirectly related to canopy nitrogen concentrations.

*LandSat ETM+*

The Landsat program is a series of optical and infrared remote sensing satellites used for land observation. The Landsat ETM+ (Enhanced Thematic Mapper Plus) provides high-resolution image information on the Earth's surface through an eight-band multispectral radiometer. The four wavebands referred to in this project are the blue (450-520 nm), green (520-600 nm), red (630-690 nm), and near-infrared (760-900 nm) (USGS 2004).

### *1.3 Objectives*

The objectives of this study were to:

1. Determine the effects of applying nitrogen as urea on sub-surface marsh nitrogen and phosphorus levels.
2. Determine whether nitrogen fertilization affected the vegetation composition and concentration of the canopy nitrogen and phosphorus of a tidal freshwater marsh.
3. Determine whether nitrogen fertilization or vegetation composition affected canopy reflectance of a tidal freshwater marsh.

4. Develop spectroradiometric models predictive of sub-surface water nutrient concentrations, vegetation composition, and canopy nitrogen and phosphorus in tidal freshwater marshes using partial least squares (PLS) regression.
5. Identify which spectral bands offer the most information about nutrient availability in tidal freshwater marshes.

### *1.4 Plan of Study*

1. To determine the effects of applying nitrogen on sub-surface nitrogen and phosphorus levels, a field experiment involving two sites of a tidal freshwater marsh and five nitrogen treatment types was conducted. Sub-surface water quality samples were analyzed throughout the 2004-5 marsh growing seasons.
2. To determine if nitrogen affected the vegetation composition and leaf nitrogen and phosphorus in a tidal freshwater marsh, percent cover of vegetation species was measured over the course of the field experiment and vegetation was harvested and analyzed for nitrogen on the last sample date in 2005.
3. To determine whether nitrogen fertilization or vegetation composition affected the canopy reflectance of a tidal freshwater marsh, canopy reflectance was measured with a spectroradiometer over the two growing seasons.
4. Partial least squares regression was used to establish models predictive of sub-surface water nutrient concentrations, vegetation composition, and canopy nitrogen and phosphorus.
5. Significant spectral bands were identified for sub-surface water nutrients in ANOVA's and PLS regression models, then compiled and compared.

# Chapter 2: Materials and Methods

## *2.1 Site Description*

Experimental plots were established in a tidal freshwater marsh along the Nanticoke River (lat 38º31'20" N, long 75º45'23" W) on the Eastern Shore of Maryland near Sharptown (Figures 2.1 and 2.2). The climate on the peninsula is humid with an average precipitation of 112 cm (Denver et al., 2001). Land use on the peninsula is mostly agricultural, specifically corn, soybeans, and chicken farms. Wetlands are common in the riparian and coastal zones, inland forests, and depressions (Denver et al., 2001). Land use within the Nanticoke watershed is 43% forested areas, 38% agricultural, 16% wetlands, and 3% urban (MD DNR 1994).

## *2.2 Experimental Design*

The experimental design used in the study was that of a completely randomized design. Two sites were established at the experimental marsh. The two sites shared many characteristics with each other, including an overlap of several vegetative species. One site was primarily dominated by the species *Phragmites australis* (Cav.) Trin ex Steud (henceforth referred to as the *Phragmites*-dominant site), while the other site contained no *P. australis* (the *Phragmites*-absent site). The *Phragmites*-dominant site had a roughly rectangular area of 1500 $m^2$ (150 m along the river, 10 m inland), while the *Phragmites*-absent site had a rectangular area of about 4000 $m^2$ (100 m along the river, 40 m inland) (Figure 2.3).

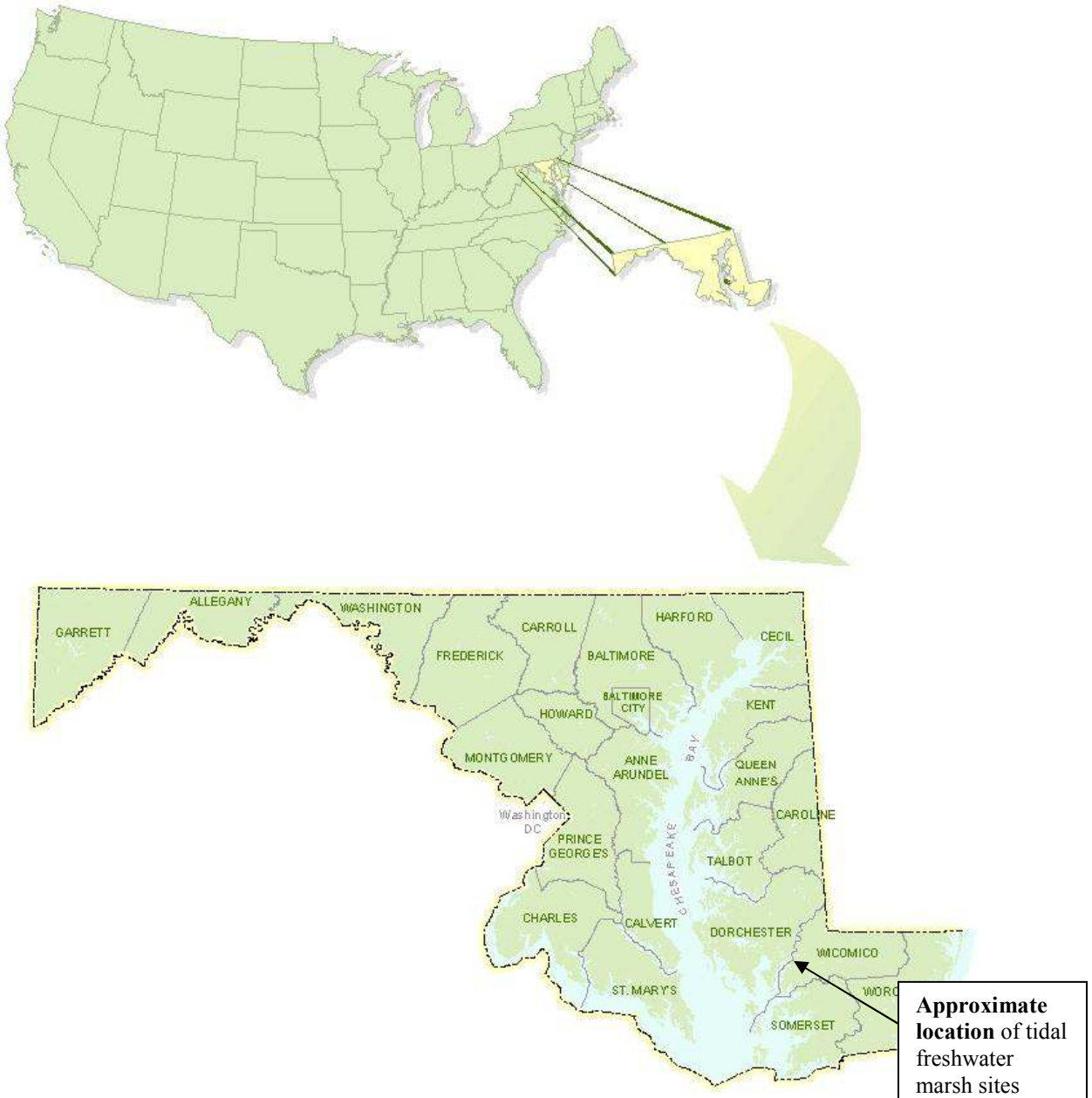



**Figure 2.1. Location of Maryland, USA (image from Harford County, MD).**

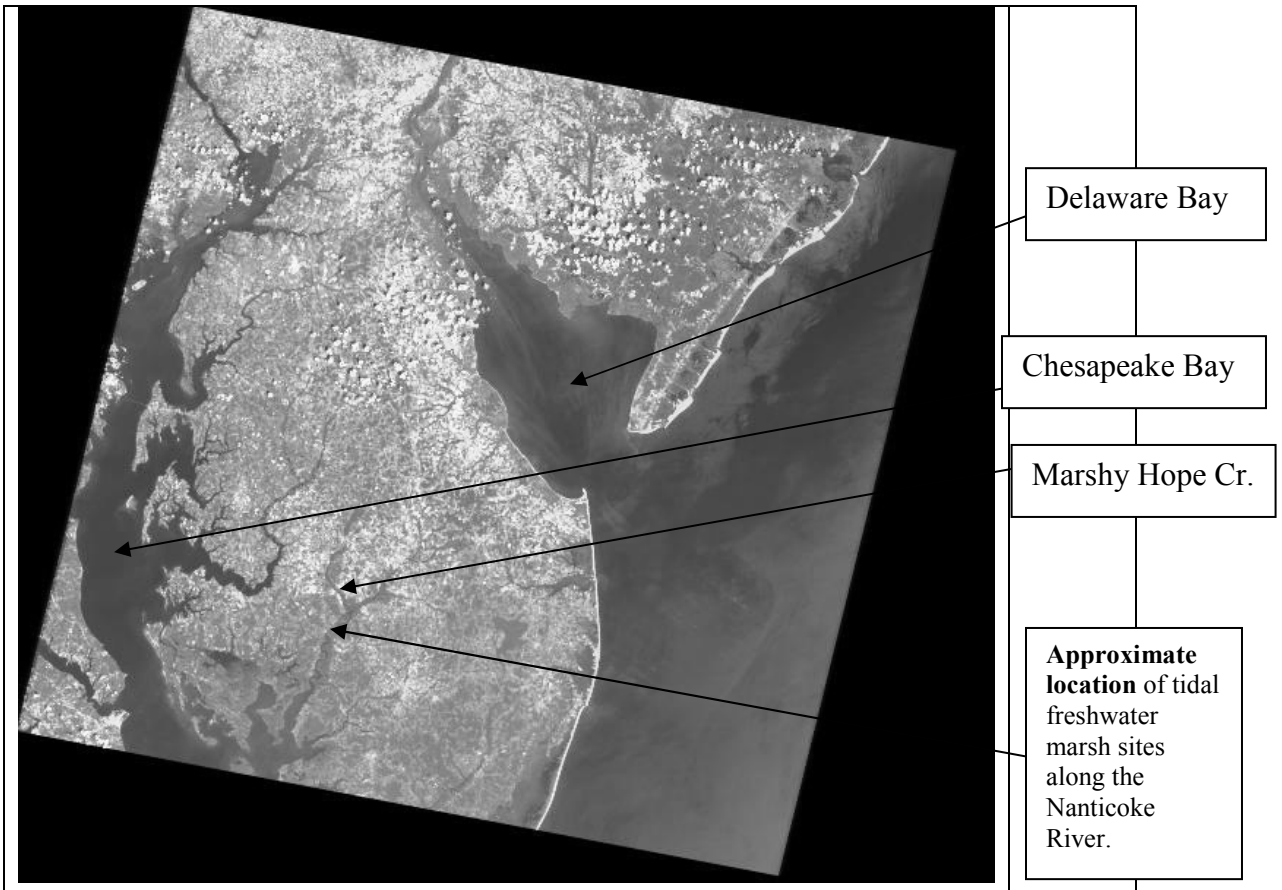
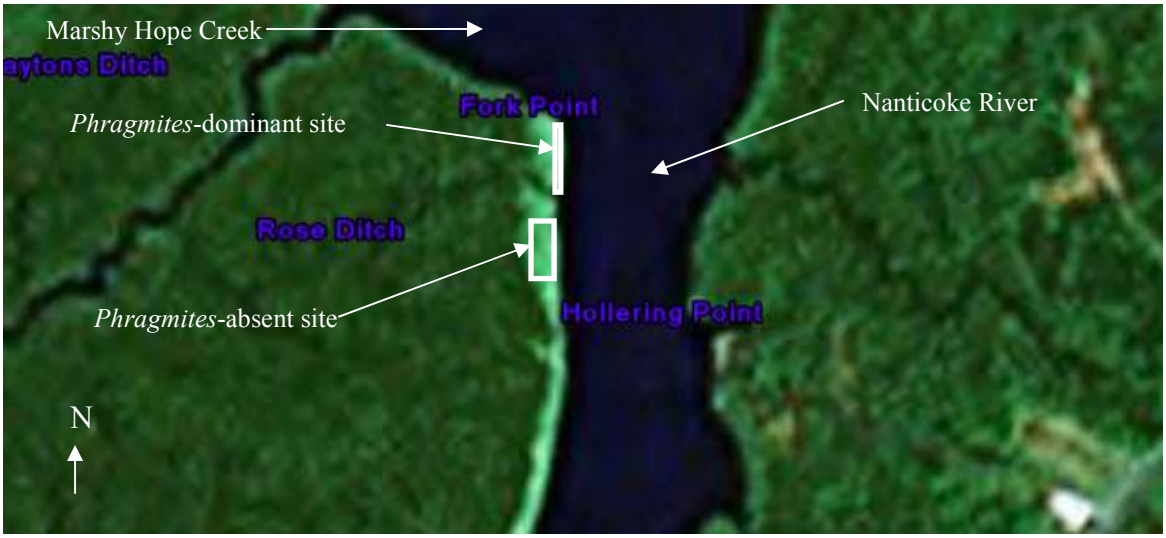



**Figure 2.2. Location of marsh sites on Delmarva Peninsula (image from NOAA).**

Plots were randomly located within each site based on a developed coordinate system where the x-axis lay parallel to the Nanticoke River and the y-axis cut inland. X-, then y-coordinates were randomly generated to determine the corner of each plot, providing plots were no closer than 10 m, if possible.



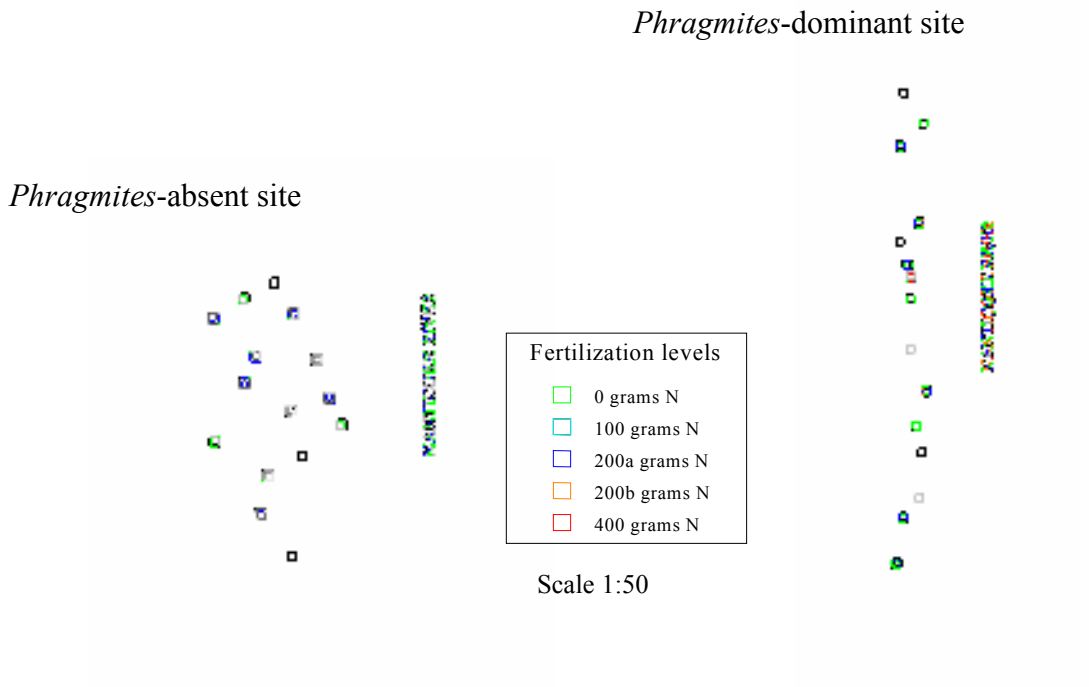




**Figure 2.3. Map of the Nanticoke River identifying the location of the two marsh sites and layout of plots according to fertilization treatment.**

On June 3, 2004, each plot was randomly chosen to receive one of five treatments of nitrogen as urea (0, 100, 200a, 200b, or 400 g-urea). Four 30 cm deep boreholes (2.5 cm diameter) were drilled into each plot, each equidistant from the plot center to its edge (Figure 2.4). Each borehole received urea either inserted in a micro-porous

dialysis tube (SpectroPor, Spectrum Labs, Rancho Dominguez, CA) or poured directly into the borehole (Feller et al., 1999). The dialysis tubes provided a slow time-release of nitrogen over the growing season, simulating a constant source of nitrogen pollution, while the boreholes created an immediate increase of nitrogen concentration in the soil, simulating a once occurring nitrogen hotspot. Boreholes not receiving urea were filled with inert perlite. The five treatments, summarized in Table 2.1, were a combination of the four urea amounts and the two application methods. Every treatment was replicated three times at each marsh site. Urea was reapplied in an identical manner during the second growing season on June 6, 2005.

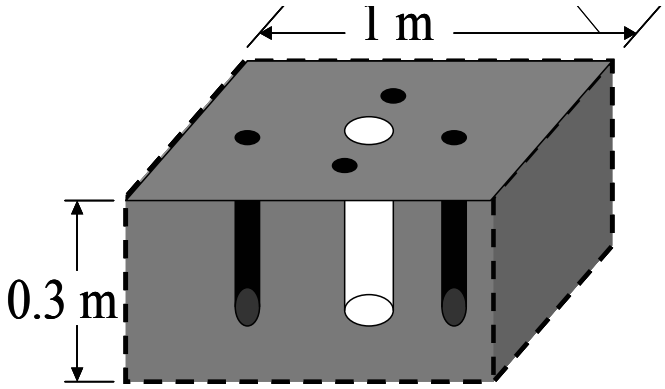



**Figure 2.4. Diagram of the lay-out for each 1 $m^2$ plot. A lysimeter was installed 30 cm deep in the center of each plot. Four boreholes were drilled, one on each side of the plot halfway between the center and the edge of the plot.**

**Table 2.1. Definition of nitrogen treatments.**

| Treatment Code | Number of Urea-filled Dialysis Tubes (D) | Number of Urea-filled Bore Holes | Nitrogen as urea (g-urea) |
|---|---|---|---|
| Ambient | 0 | 0 | 0 |
| N100 | 1 | 0 | 100 |
| N200/1D | 1 | 1 | 200 |
| N200/2D | 2 | 0 | 200 |
| N400 | 2 | 2 | 400 |

Ceramic-tipped lysimeters (Soil Moisture Inc, CA) were installed in the center of each plot at a depth of 30 cm and covered by a layer of Bentonite to prevent water and air leaks. Two colored polyethylene tubes connected to the lysimeters ran to the edge of the plot for water sample collection. The black tube was used to connect a hand operated pump/vacuum to pressurize and evacuate the lysimeters. The green tube was used to fill sample containers with sub-surface water. The lysimeters were purged of all water before the vacuum was set, and then both tubes were folded closed to hold the vacuum until the sample water was extracted.

### *2.3 Data Collection*

Canopy reflectance, sub-surface water nutrients, percent cover class, and leaf area index (LAI) at all plots were measured biweekly in June 2004 following initial fertilization in late May, then once monthly from July through September 2004. The same measurements were taken for the following year (2005) in early June and early August. Biomass and canopy nutrients were measured at the conclusion of the experiment, in August 2005.

An ASD Handheld SpectroRadiometer (Analytical Spectral Device, Boulder, CO) was used to measure canopy reflectance from 325-1075 nm (750 spectral bands) of each marsh plot. Spectroradiometric measurements were taken in full sunlight between 10 am and 3 pm. The radiometer was attached to a uni-pod fixed at a 20° angle to a long plastic rod that was anchored into the ground approximately 1.5 m away from the middle of the north side of each plot (Figure 2.5). The radiometer's

25° field-of-view bare-optic sensor pointed straight down towards the plot, 3.5 m above the ground surface, such that the entire 1 $m^2$ plot was viewed. Percent reflectance was calculated by dividing the canopy reflectance readings by the reflectance of a calibrated Spectralon white panel (Labsphere, Inc., North Sutton, NH), which was held on a long pole directly under the radiometer before plot readings were taken. The spectroradiometer collected ten 76 or 168 millisecond readings of each plot canopy which were later averaged to estimate mean plot reflectance.

**Figure 2.5. Canopy reflectance measured at the *Phragmites*-absent site (8/24/04). The radiometer is mounted on the long pole centered over the plot, and is reading the reflectance of the calibrated white panel. The sample plot is marked by the long, thin pole with flagging at one corner and a smaller pole, not visible here, at the opposite corner.**

Sub-surface water samples of 250 mL were taken from the 400 mL lysimeter by first purging the lysimeter with the hand pump (Figure 2.6). A vacuum was then set and

left for 6 to 24 hours to allow the lysimeter to draw in sub-surface water. A water sample was pumped from the lysimeter at each plot to a labeled sample bottle and preserved on ice at a pH of 2 until analysis testing was conducted. A full water sample was not always attained at each site; occasionally the lysimeter did not have a sufficient amount of time to pull enough water to fill a sample container.

**Figure 2.6. Sub-surface water collected at the *Phragmites*-dominant site (6/16/04). Water was collected 6 to 24 hours after the vacuum was set on the lysimeter.**

Water samples were analyzed using the Hach DR/2010 Spectrophotometer (Hach Company, Loveland, CO) for ammonia, nitrate, total phosphorus, and total nitrogen. Method #8038 for ammonia mixed Mineral Stabilizer, Polyvinyl Alcohol dispersing Agent, and Nessler Reagent to each water sample and measured ammonia at 425 nm, using deionized water as the blank. Method #8039 used NitraVer 5 Nitrate Reagent Powder to analyze nitrate at 500 nm against the original sample as a blank. Total

phosphorus was analyzed according to Method #8190, which used Potassium Persulfate and heat before the sample was measured at 890 nm. Total nitrogen analysis required Method #8075, which first involved digestion of the sample with the Digesdahl heater (Hach Company, Loveland, CO), and evaluation of nitrogen concentration at 460 nm. For quality control, several ammonia and nitrate concentration solutions were prepared, split in half, and analyzed using Hach DR/2010 Spectrophotometer methods, while the other half was analyzed at Washington Suburban Sanitary Commission (WSSC). WSSC used automated flow injection analysis methods to analyze ammonia using method EPA 350.1 (Lachat 10-107-06-1-A) (Lachat Instruments, Milwaukee, WI) and nitrate with EPA 353.2 (Lachat 10-107-04-1-A) (Lachat Instruments, Milwaukee, WI). Both the Hach DR/2010 and WSSC analyses yielded similar ammonia and nitrate concentrations.

The surface cover of vegetation, dead material (i.e., brown, senescent), surface water, exposed soil, and bentonite/perlite (installed with the lysimeters and N-fertilizations) was quantified for each plot according to a cover class system used by the North Carolina Vegetation Survey (Peet et al., 1998). The cover of each plant species found within the one-meter quadrat was recorded and assigned a classification number (Table 2.2) based on its percent cover of the quadrat. The cover class system had higher resolution at the lower end of the scale than at the higher end.

Species richness was determined by summing the number of species observed at each plot, and the diversity index was calculated according to the Shannon-Wiener diversity index (H):

$$H = -\sum(n_i/N)\ln(n_i/N)$$

where n is the cover of each species i, and N the total cover of all species.

**Table 2.2. Cover Class System (Peet et al., 1998)**

| Class | Cover Range |
|---|---|
| 1 | a trace amount |
| 2 | 0-1% |
| 3 | 1-2% |
| 4 | 2-5% |
| 5 | 5-10% |
| 6 | 10-25% |
| 7 | 25-50% |
| 8 | 50-75% |
| 9 | 75-95% |
| 10 | 95-100% |

The leaf area index (LAI) of each plot was measured and recorded with an LAI-2000 Plant Canopy Analyzer (Li-Cor, Lincoln, NE). The optical sensor of the LAI-2000 was held above the canopy for one reading, then within the plot at approximately 10 cm above ground level for two consecutive readings to estimate LAI as the area of foliage per unit area of ground.

Total biomass of each plot was collected on 8/02/05 after other measurements were collected. All standing vegetation in the plot was cut at ground level and bagged for transport. At the lab, biomass at each plot was sorted according to species, dried at 70 ºC, and weighed. The dried tissue was ground and sent to the University of Delaware Soil Testing Program for canopy nitrogen and phosphorus analysis. Total

nitrogen and total carbon in the tissue was measured by the combustion technique using an Elementar Vario-Max CN analyzer (Elementar Americas, Inc., Mt. Laurel, NJ). Samples were digested for elemental composition using a CEM MARS-5 microwave digestion system (CEM Corporation, Matthews, NC). Digests were analyzed for P, K, Ca, Mg, Mn, Cu, Zn, Fe, B, S and Al by emission spectroscopy using a Thermo IRIS Intrepid II – XSP Duo View inductively coupled plasma-optical emission spectrometer (Thermo Electron Corp., Madison, WI).

### *2.4 Data Analysis*

Analysis of variance (ANOVA) was conducted to study treatment effects on sub-surface water nutrient concentrations, vegetation composition data, biomass, canopy nitrogen and phosphorus concentrations, and spectral band reflectance and reflectance indices. Reflectance indices examined included three simple reflectance ratios ($R_{493}/R_{678}$, $R_{415}/R_{710}$, and $R_{564}/R_{768}$), the Photochemical Reflectance Index (PRI), and a standard Normalized Difference Vegetation Index (NDVI).

I conducted repeated measures ANOVAs to determine the effect of time, site, treatment, and their interactions on each parameter. Time effects were further investigated with treatment effect at individual sites using repeated measures ANOVA. I also used a univariate general linear model ANOVA at each sample date, with fixed factors as treatment and site, to determine whether nitrogen, site, or their interaction produced significant responses in sub-surface water nutrient concentrations, vegetation cover composition data, biomass, canopy nutrient

concentrations, and reflectance at each narrow spectral band. Comparison of means was examined using the least significant difference (LSD) test in SPSS for Windows (SPSS Inc., Chicago, IL) for each sample date and marsh site. Significant differences were defined at the 0.05 probability level.

Linear regressions were used to determine relationships between reflectance and time, sub-surface water nutrients and canopy nutrients, as well as biomass and LAI, diversity, species richness, and canopy nutrients.

Partial least squares regression was used to develop models of hyperspectral reflectance predictive of sub-surface water nitrogen (in forms of ammonia, nitrate, and total nitrogen) and total phosphorus, as well as cover of vegetation, dead material, exposed soil, LAI, species richness, diversity index, canopy nitrogen and phosphorus, and biomass. All PLS regressions were performed using Unscrambler 9.0 (Camo Process AS, Oslo, Norway).

For validation of the PLS model, both the full-cross method (i.e. leave-one-out) and the test set method were performed. The optimal number of PLS-components (i.e. independent latent factors) included in the final model corresponded to the model with the minimum root mean square error of prediction (RMSEP), which is the square root of the residual mean square that estimates the common within-group standard deviation. The Martens Uncertainty Test within Unscrambler was applied to each

PLS regression to determine significant spectral bands. Bands found to be insignificant were removed and a new model was built with remaining bands.

### *2.4.1 Reflectance Transformations for ANOVA and PLS Modeling*

Several data preprocessing transformations were performed on spectroradiometric data during ANOVA and PLS-regression modeling. Pre-processing transformations used on reflectance data included:

- a truncated reflectance curve,
- normalized reflectance,
- inverse reflectance,
- log of the reflectance,
- Norris method first derivative of the reflectance,
- Golay method first derivative of the reflectance
- Golay method second derivative of the reflectance,
- multiplicative scatter correction (MSC),
- absorbance transformation, and
- Kubelka-Munk transformation.

All transformations were performed on all data so comparisons could be made between transformations.

An example of a typical untransformed reflectance curve for the tidal freshwater marsh is shown in Figure 2.7. Examples of each transformation are based on their typical reflectance curve.

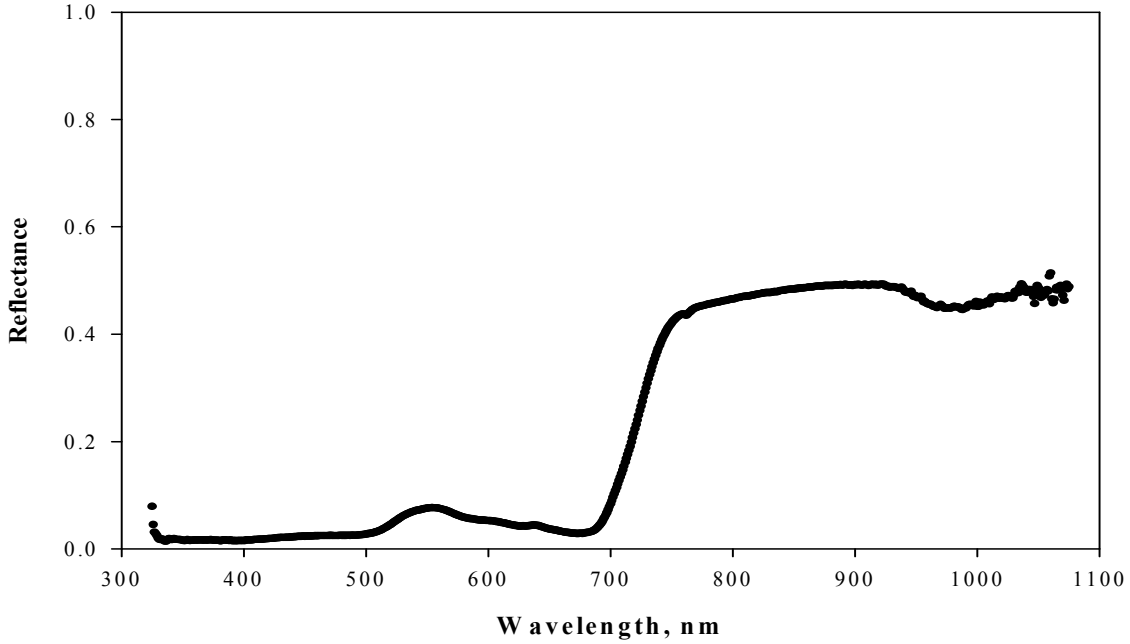



**Figure 2.7. A typical untransformed spectral reflectance curve for the tidal freshwater marsh canopy during the middle of the 2004 growing season.**

*Truncated reflectance curve*

The truncated reflectance curve, included only untransformed spectral bands between 400 and 950 nm (Figure 2.8). By using the truncated curve, much of the noise reported by the radiometer at each end of its range was eliminated.

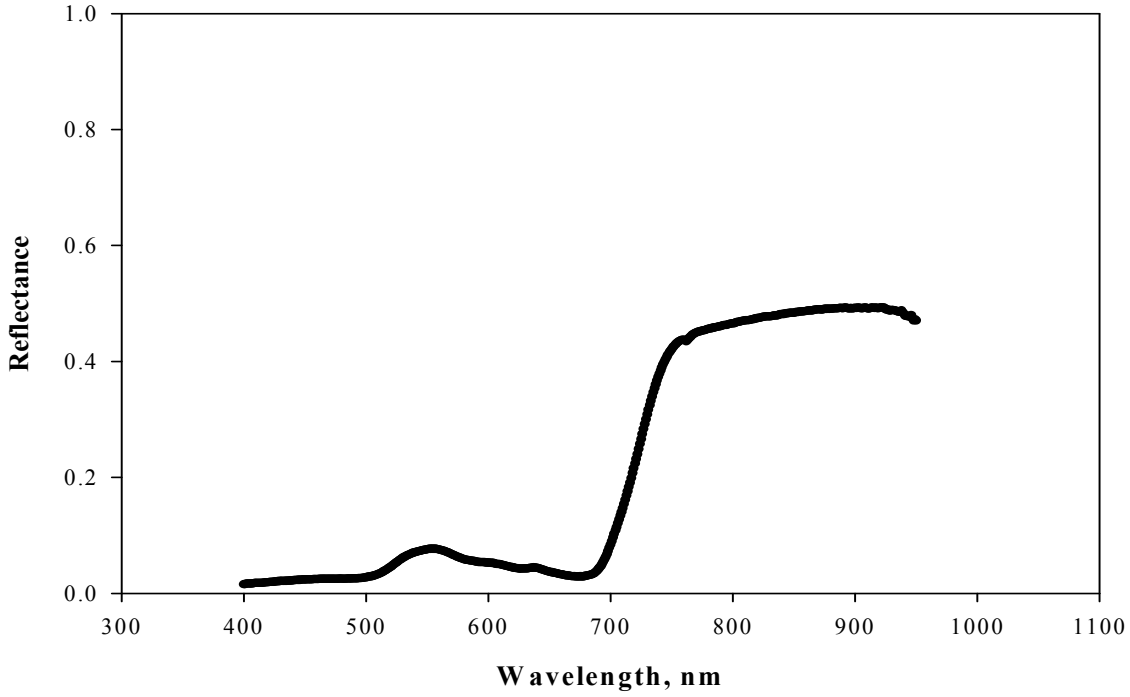



**Figure 2.8. A truncated (400-950nm) spectral reflectance curve for the tidal freshwater marsh canopy during the growing season.**

*Normalized reflectance curve*

Normalization of reflectance curves was performed to compensate for small reflectance variations in individual plots (Figure 2.9). To normalize the data, the reflectance at each spectral band was divided by the reflectance at spectral band $R_{410}$ (see equation 1).

$$R_{norm} = R_{\lambda}/R_{410} \qquad \text{Equation 1}$$

$R_{410}$ was chosen as the normalization wavelength because the amount of reflectance at $R_{410}$ had the lowest variance of all spectral bands. The normalized reflectance curve rescaled the original curve, thereby removing variation.

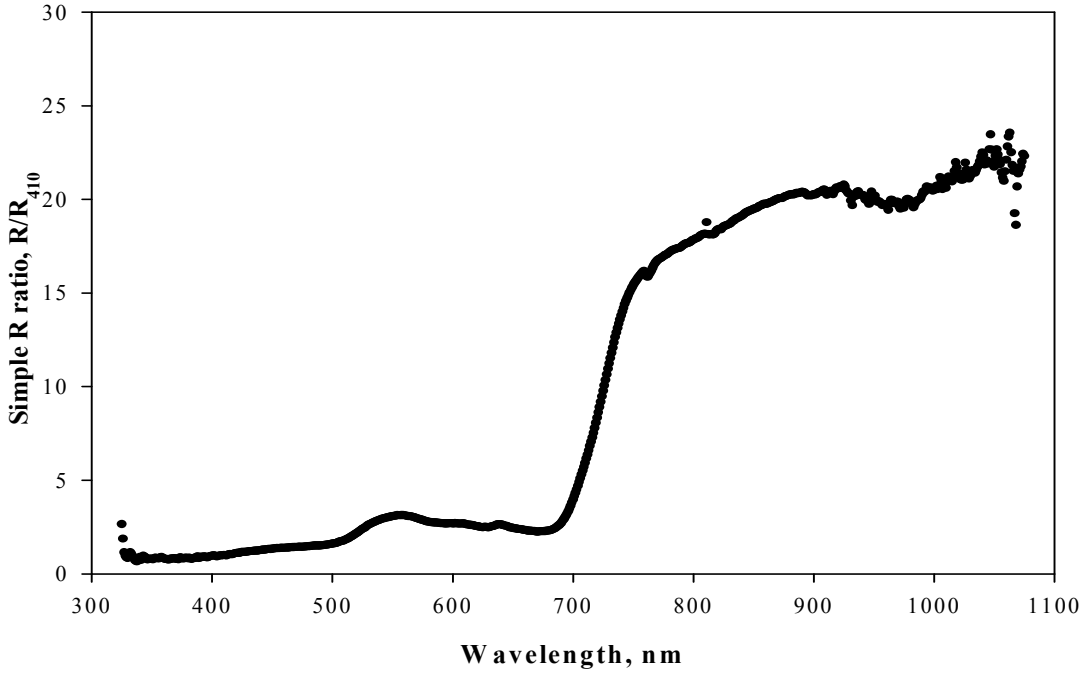



**Figure 2.9. Normalized ($R/R_{410}$) (and not truncated) spectral curve for a tidal freshwater marsh canopy.**

*Inverse reflectance curve*

The inverse of the typical reflectance curve is shown in Figure 2.10 and is characterized by taking one over the reflectance at each spectral band (Equation 2).

$$R_{inv} = 1/R \qquad \text{Equation 2}$$

The inverse transformation is often used in traditional statistics to improve data normality; for spectroradiometric data, it inverts the reflectance curve.

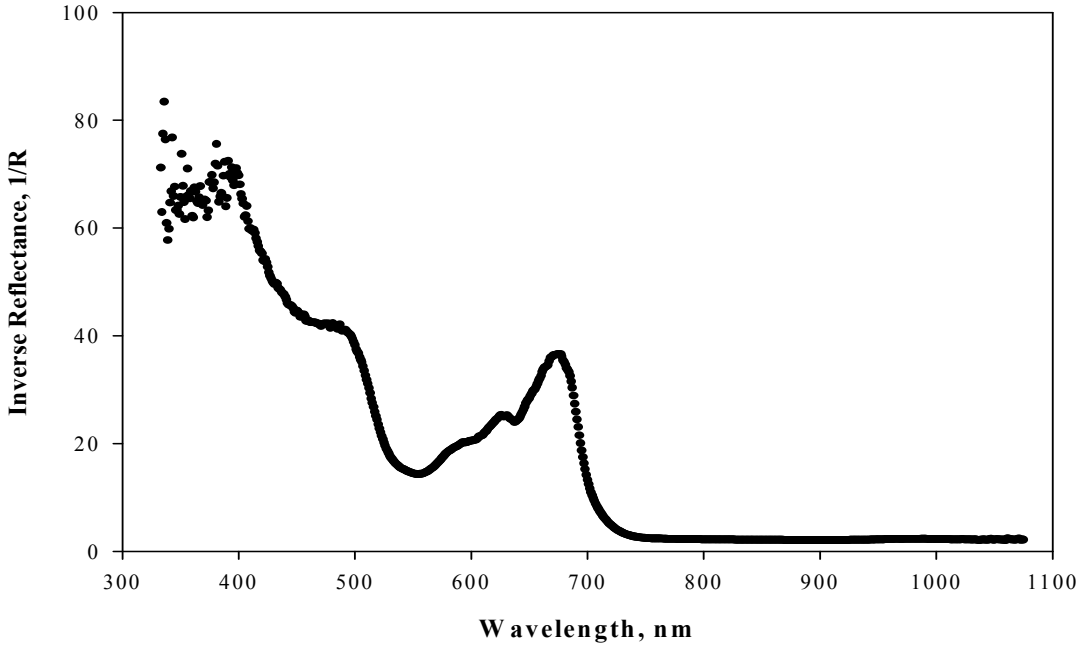



**Figure 2.10. An inverse (1/R) spectral curve for a tidal freshwater marsh canopy.**

*Log reflectance curve*

Figure 2.11 shows the log of the reflectance performed for each spectral band's reflectance (Equation 3).

$$\log R = \log_{10} R \qquad \text{Equation 3}$$

The log of the reflectance (log R) converted the multiplicative relationship of the reflectance and dependent variable to an additive one in an attempt to improve the linearity of the regression relationship. Multiplicative relationships assume that factors change the dependent variable by multiplication or division, while additive models assume factors change the dependent variable by addition or subtraction and hence give a more linear relationship than multiplicative models. Several researchers have used the log transformation to find relationships between leaf nitrogen and reflectance information (Grossman et al., 1996; Retisco et al., 2005).

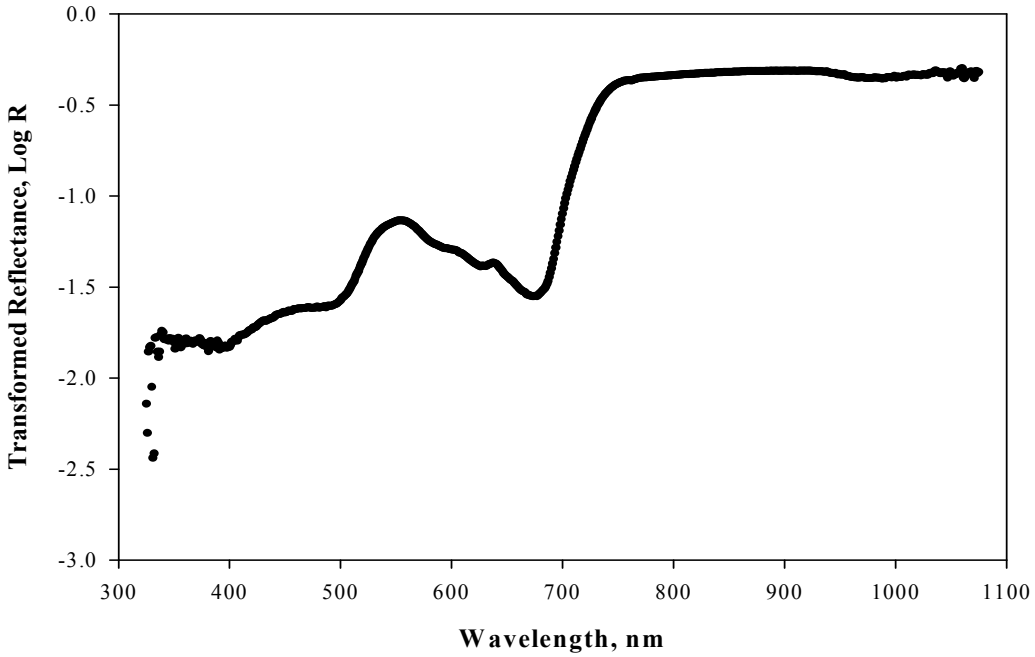



**Figure 2.11. The log of a reflectance curve for a tidal freshwater marsh canopy.**

*First derivative of a reflectance curve*

The first derivative of the reflectance curve is a measure of the slope for the spectral curve at every band and results in a spectrum in which peaks and valleys correspond with inflection points in the reflectance spectra (Equation 4). The first derivative typically is used to correct baseline shifts, resolve overlapping spectral peaks, and minimize low-frequency variation (Smith et al., 2002).

$$1^{st} \text{ derivative } R = d(R_\lambda)/d\lambda \qquad \text{Equation 4}$$

Two different methods can be used in the program Unscrambler to differentiate spectral data: the Norris method and the Savitzky- Golay (Golay) method. The Norris method only calculates 1st derivatives, while the Golay method can calculate 1st and higher order derivatives. Both methods include a smoothing factor in their

separate algorithms which determines how many adjacent bands will be used in the derivation.

The 1st derivative (Norris) of a plot reflectance curve (Figure 2.12), the Golay 1st derivative of a reflectance curve (Figure 2.13), the 1st derivative (Norris) with a smoothing factor of 5 bands (Figure 2.14), and the 1st derivative (Norris) with a smoothing factor of 10 bands (Figure 2.15), all show the same major spectral features (eg. peak at 700 nm), but differ slightly where derivatives were small (eg. between 600 – 700 nm).

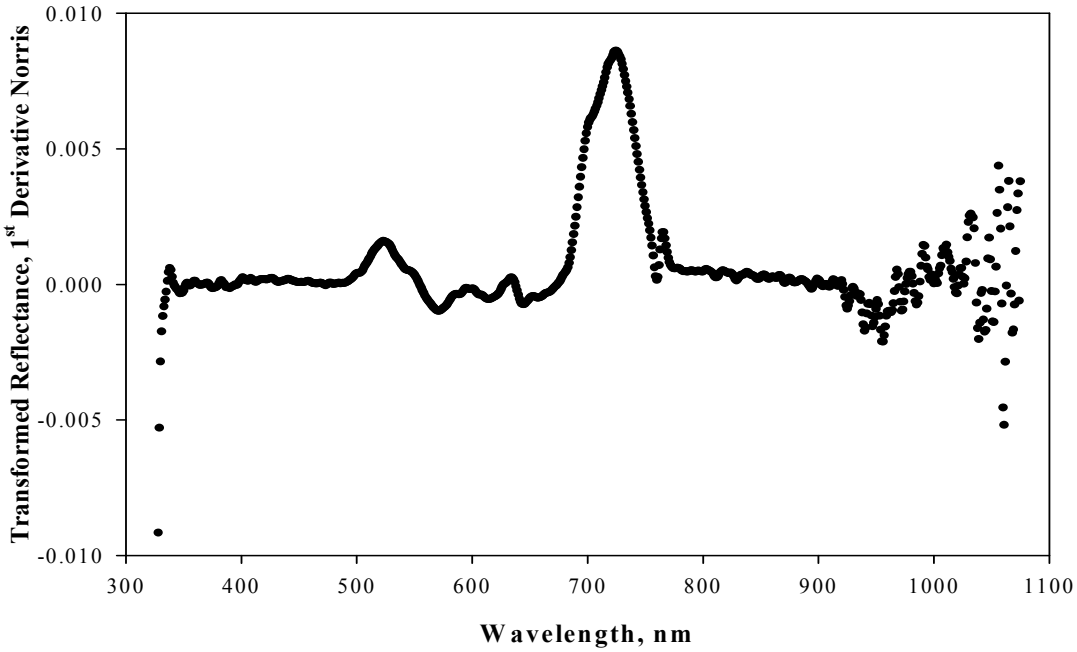



**Figure 2.12. The Norris 1st derivative reflectance curve for a tidal freshwater marsh canopy**

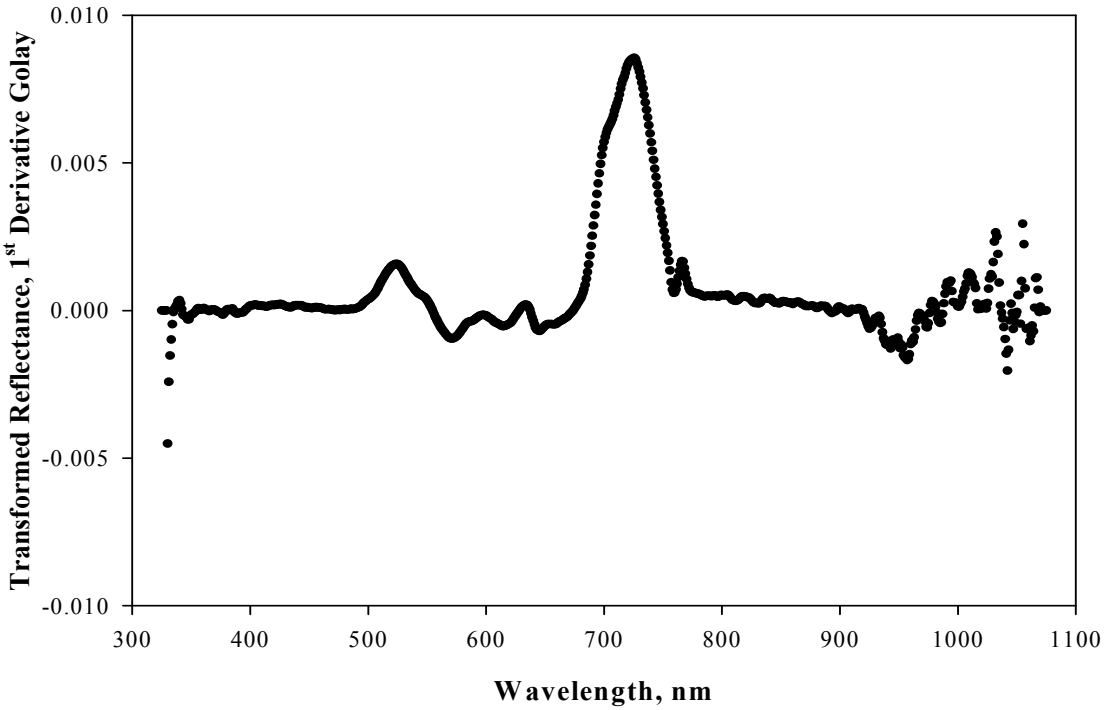



**Figure 2.13. The S. Golay 1st derivative reflectance curve for a tidal freshwater marsh canopy**

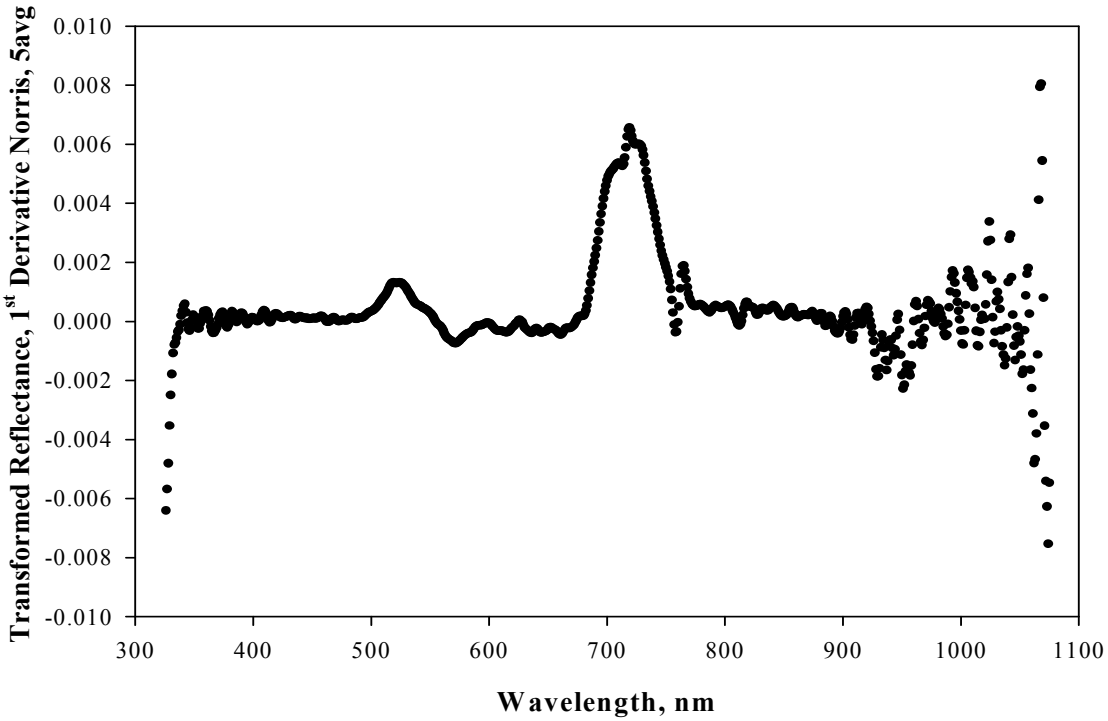



**Figure 2.14. The Norris 1st derivative reflectance curve for a tidal freshwater marsh canopy, with five adjacent bands averaged together.**

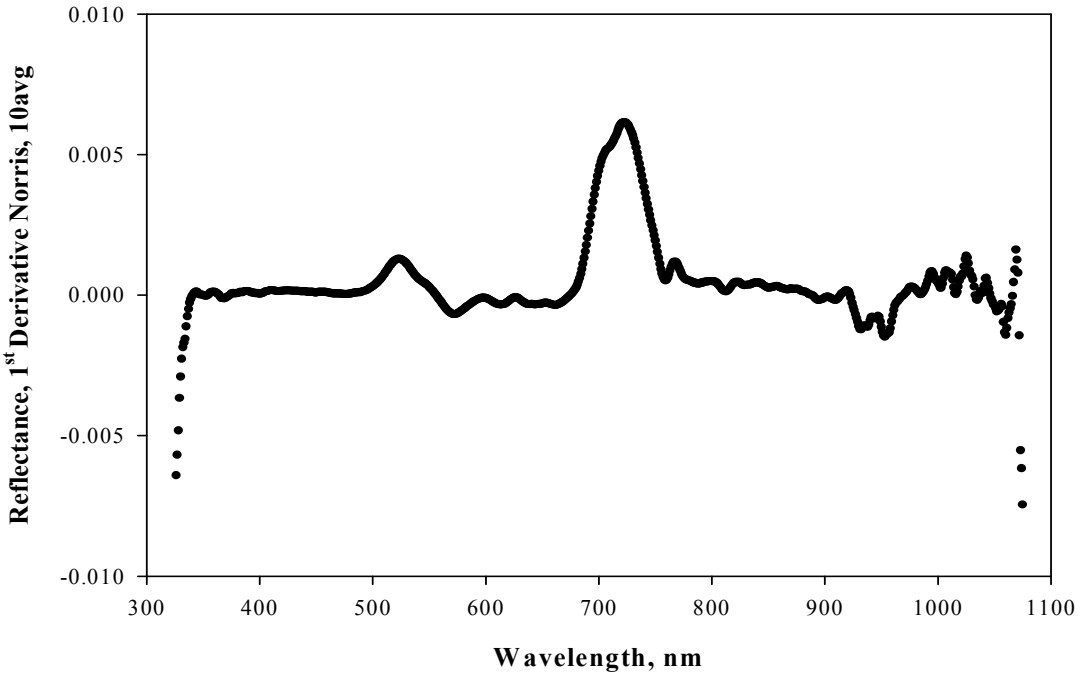



**Figure 2.15. The Norris 1st derivative reflectance curve for a tidal freshwater marsh canopy, with ten adjacent bands averaged together.**

*Second derivative of a reflectance curve*

Second derivatives correct scatter effects in reflectance curves to better correlate hyperspectral data to vegetation components (Becker et al, 2005) and nitrogen concentrations (Smith et al., 2002; Petisco et al., 2004). The equation for the second derivative of reflectance is shown in Equation 5.

$$2^{nd} \text{ derivative } R = d^2R/d\lambda^2 \qquad \text{Equation 5}$$

For Golay 2nd derivatives we always averaged 10 adjacent spectral bands. Figure 2.16 displays the 2nd derivative of the reflectance curve of a typical tidal freshwater marsh canopy.

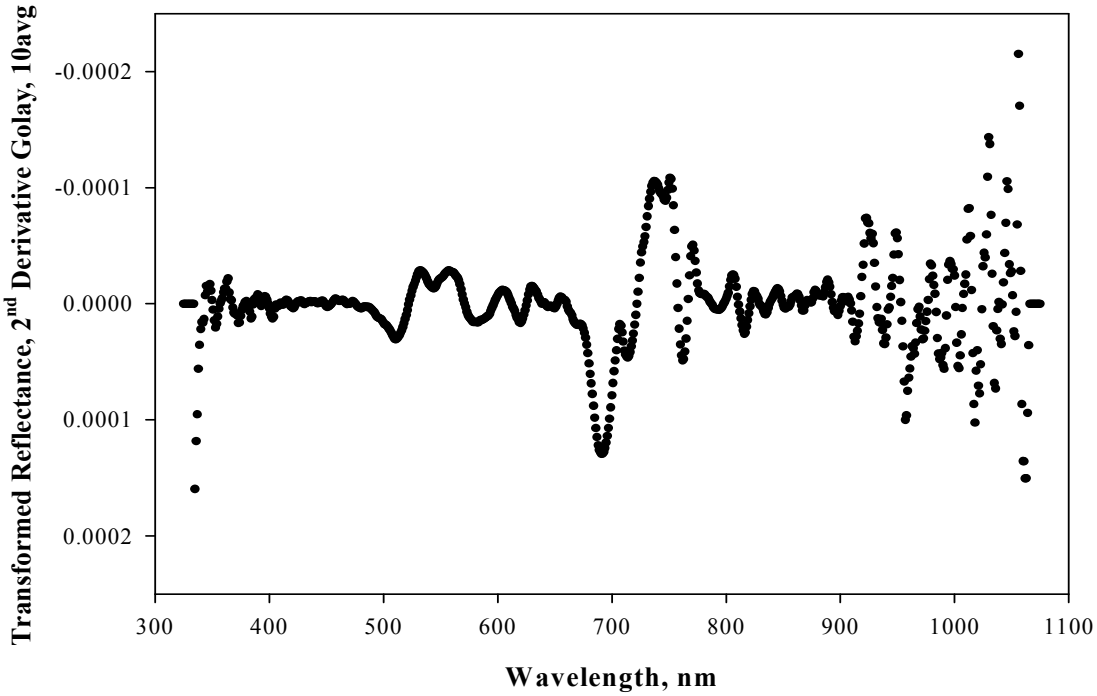



**Figure 2.16. The S. Golay 2nd derivative (averaging 10 wavebands) for a typical tidal freshwater marsh canopy.**

*Multiplicative scatter correction (MSC) of a reflectance curve*

Multiplicative scatter correction (MSC) removes both multiplicative and additive light scattering effects from the spectral data. Scatter effects in reflectance data may be caused by background effects and air temperature and pressure variations, all of which are composed of multiplicative and additive effects. MSC removes all effects with a corrective regression model (Equation 6).

$$R_{MSC} = [R_\lambda - A(i)] / B(i) \qquad \text{Equation 6}$$

(A = intercept of the regression line, B = slope of the regression line, i = sample)

Figure 2.17 illustrates the MSC transformation of a typical reflectance curve of a tidal freshwater marsh canopy.

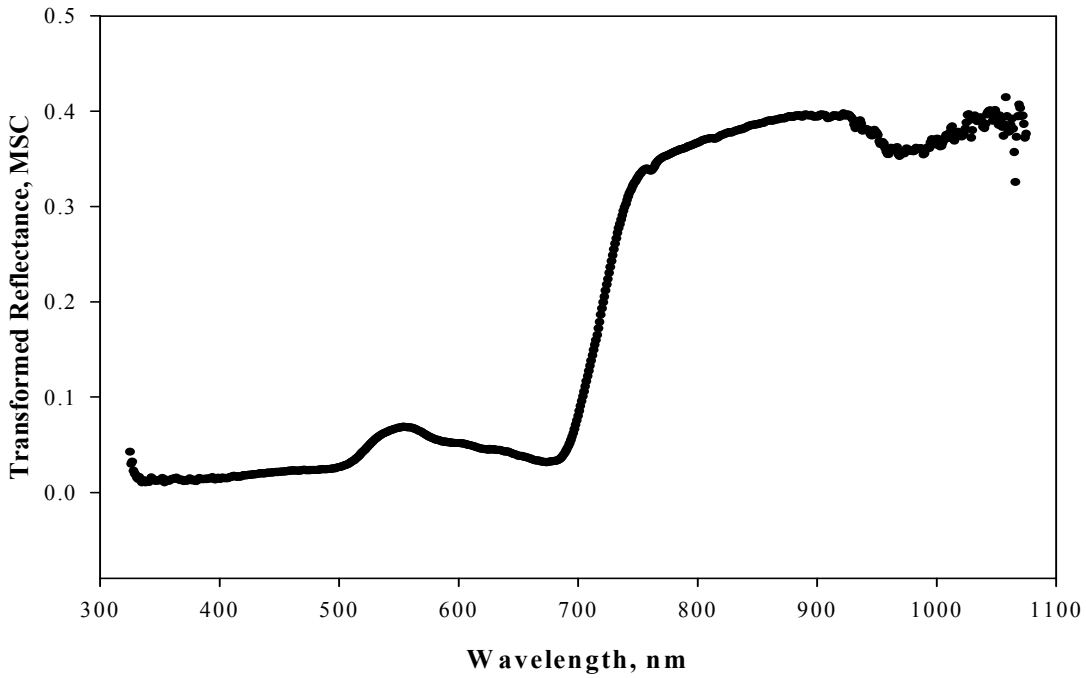



**Figure 2.17. A multiplicative scatter correction (MSC) curve for a typical tidal freshwater marsh canopy.**

*Absorbance curve*

Reflectance curves transformed into absorbance curves using Equation 7 have been correlated to vegetation components in PLS-regressions (Grossman et al., 1996; Smith et al., 2002; Petisco et al, 2005).

$$R_{abs} = \log_{10}(1/R_{\lambda}) \qquad \text{Equation 7}$$

The absorbance transformation combines the inverse and log transformations, which yields an inverse reflectance curve minimizing the differences between high and low reflectance bands (Figure 2.18).

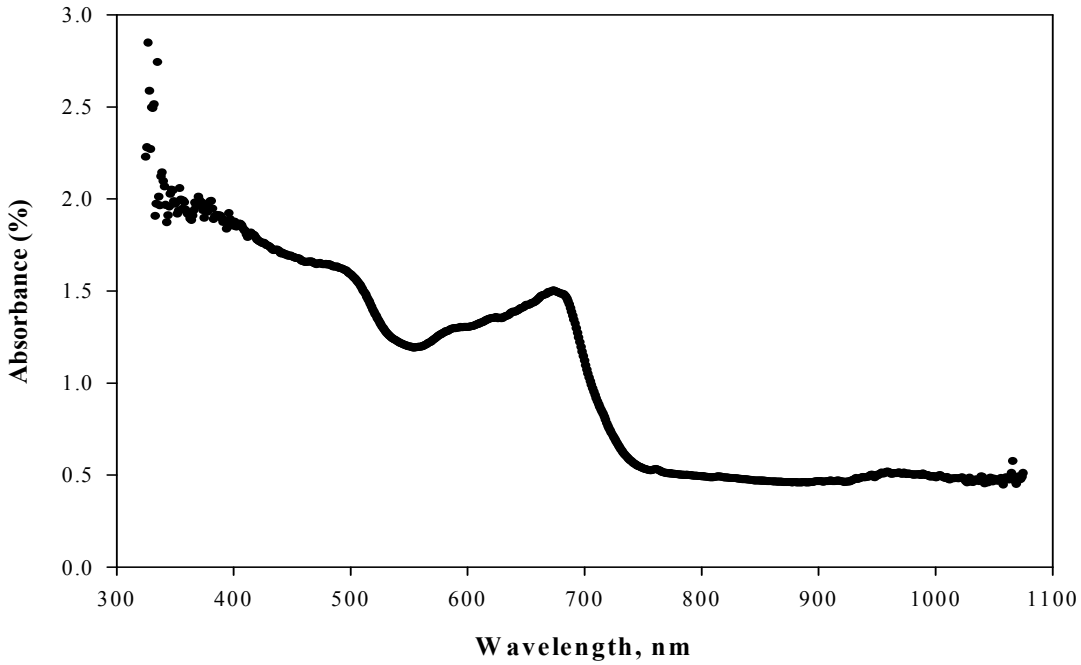



**Figure 2.18. An absorbance curve for a tidal freshwater marsh canopy**

*Kubelka-Munk transformation of a reflectance curve*

Reflectance curves were also transformed into Kubelka-Munk units (Equation 8). The Kubelka-Munk transformation is a type of inverse reflectance function that helps to reduce scattering effects in reflectance data (Figure 2.19).

$$R_{KM} = (1-R_\lambda)^2/(2R_\lambda) \qquad \text{Equation 8}$$

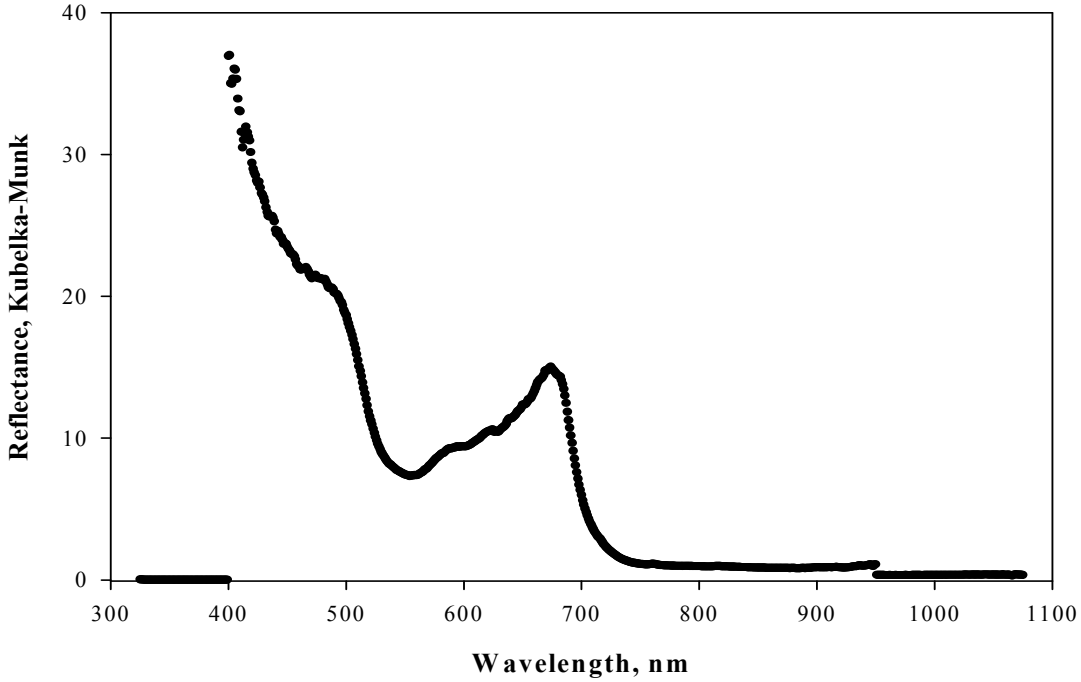



**Figure 2.19. A Kubelka-Munk absorbance curve for a tidal freshwater marsh canopy.**

*2.4.2 Dependent Data Transformations for ANOVA and PLS Modeling*

Water quality and vegetation component transformations used for all ANOVA and PLS-modeling included the log of concentration, the square root of concentration, arcsine of the square root of concentration, and the fourth root concentration. The untransformed water quality data had skewed frequency distributions with a few high concentrations and a majority of low concentrations. For example, $NH_3$ untransformed concentrations are shown in Figures 2.20, demonstrating the skewed distribution. Examples of the effect of each transformation on water quality data are shown in Figures 2.21 – 2.24.

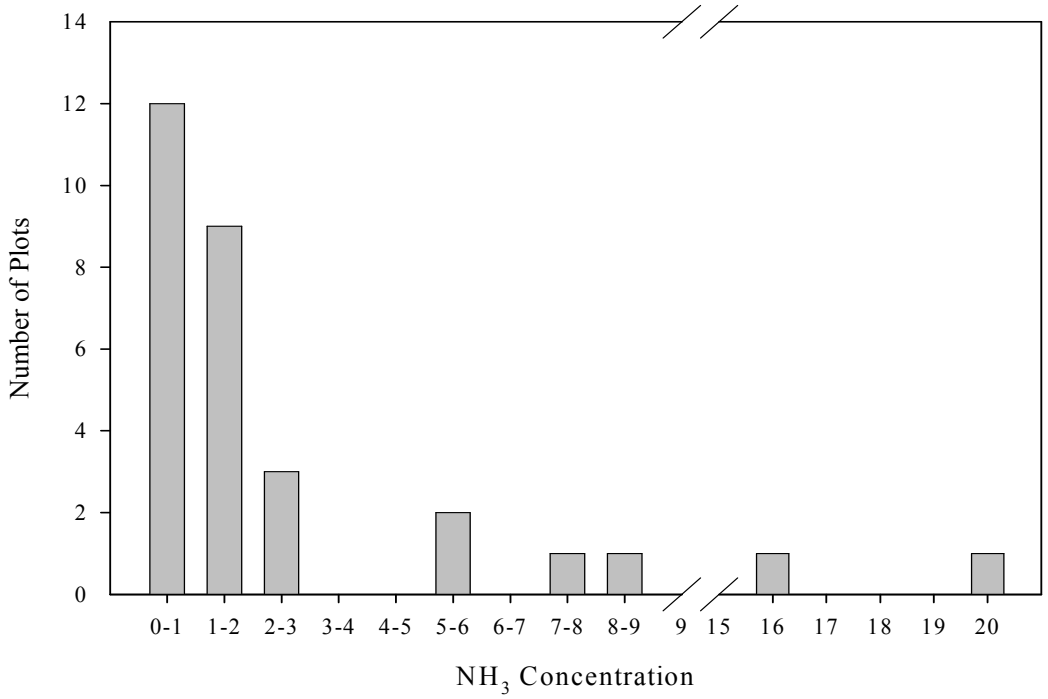



**Figure 2.20. The frequency distribution of $NH_3$ concentrations for plots at the two marsh sites on 8/24/04.**

*Log of concentration*

The log of the concentration (Figure 2.21) produced a more normal distribution than the untransformed data (Figure 2.20). For the log transformation shown in Figure 2.22, the $\log_{10}$ was taken of each concentration (Equation 9).

$$\log \text{Conc} = \log_{10}(\text{Conc}) \qquad \text{Equation 9}$$

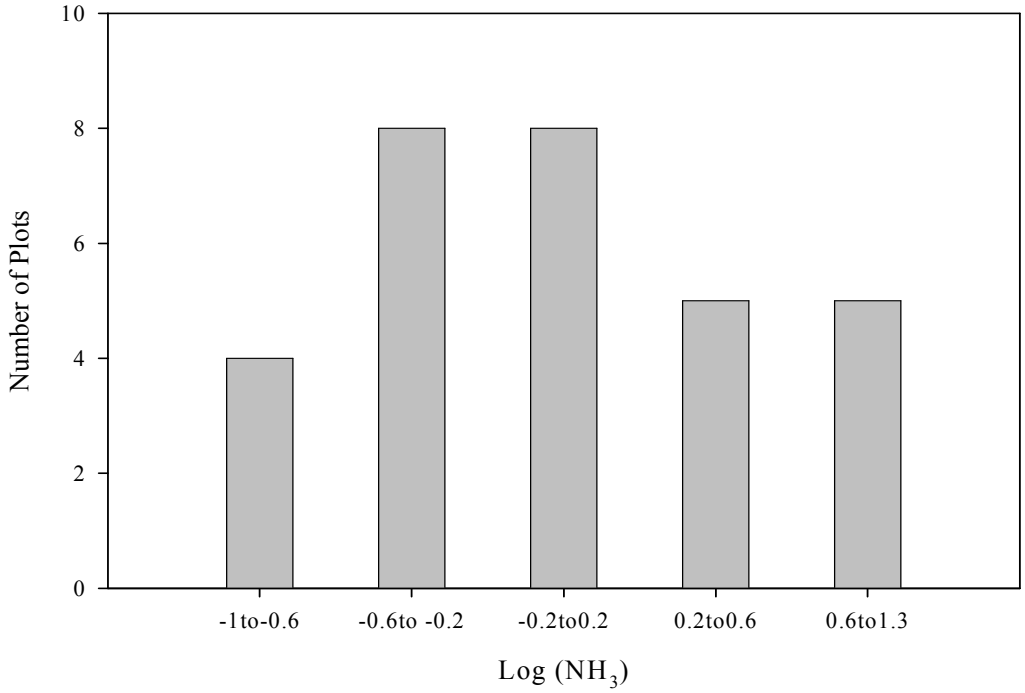



**Figure 2.21. The distribution of the Log ($NH_3$) transformation for plots at the two marsh sites on sample date 8/24/04.**

*Square root of concentration*

The square root of the dependent variable is commonly used in statistics to create a normal distribution from skewed data (Equation 10). Figure 2.22 shows the transformed distribution for the square root of the concentration.

$$Conc_{sqrt} = (Conc)^{1/2} \qquad \text{Equation 10}$$

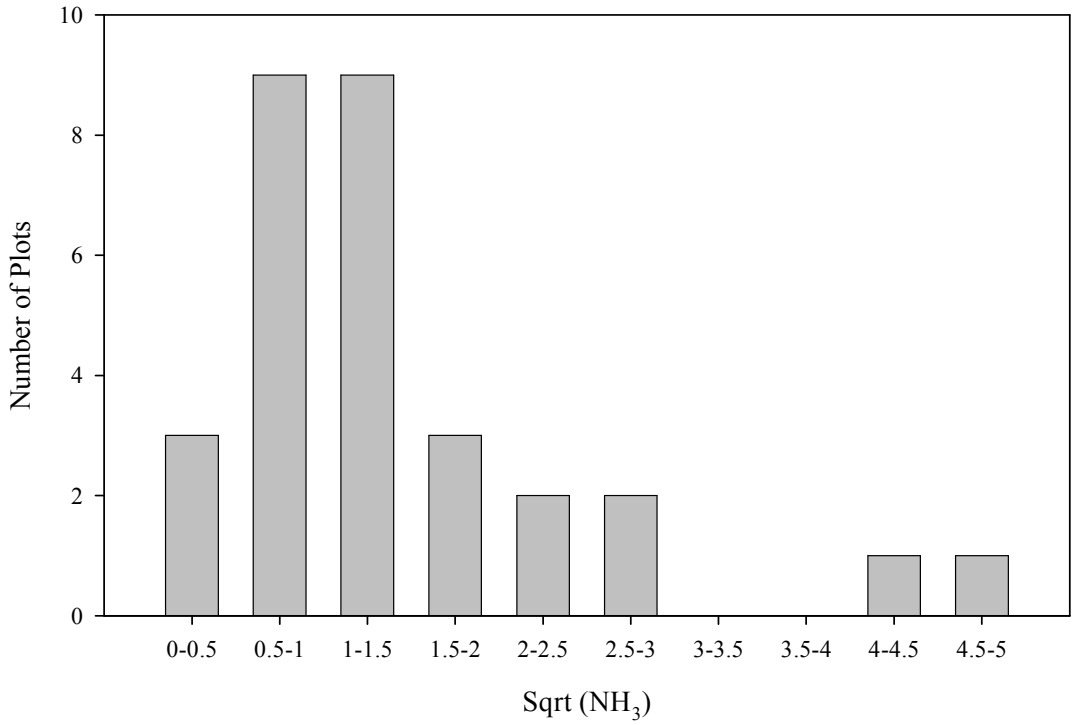



**Figure 2.22. The distribution of the square root transformation of $NH_3$ for plots at the two marsh sites on sample date 8/24/04.**

*Arcsine of the square root of concentration*

The arcsine of the square root of concentration transformation (Equation 11) has been used to normalize the dependent variable data in statistics. The transformed distribution had a much smaller range, but still had a skewed distribution (Figure 2.23).

$$Conc_{arcsin} = \text{Arcsine } (\text{sqrt}(Conc)) \qquad \text{Equation 11}$$

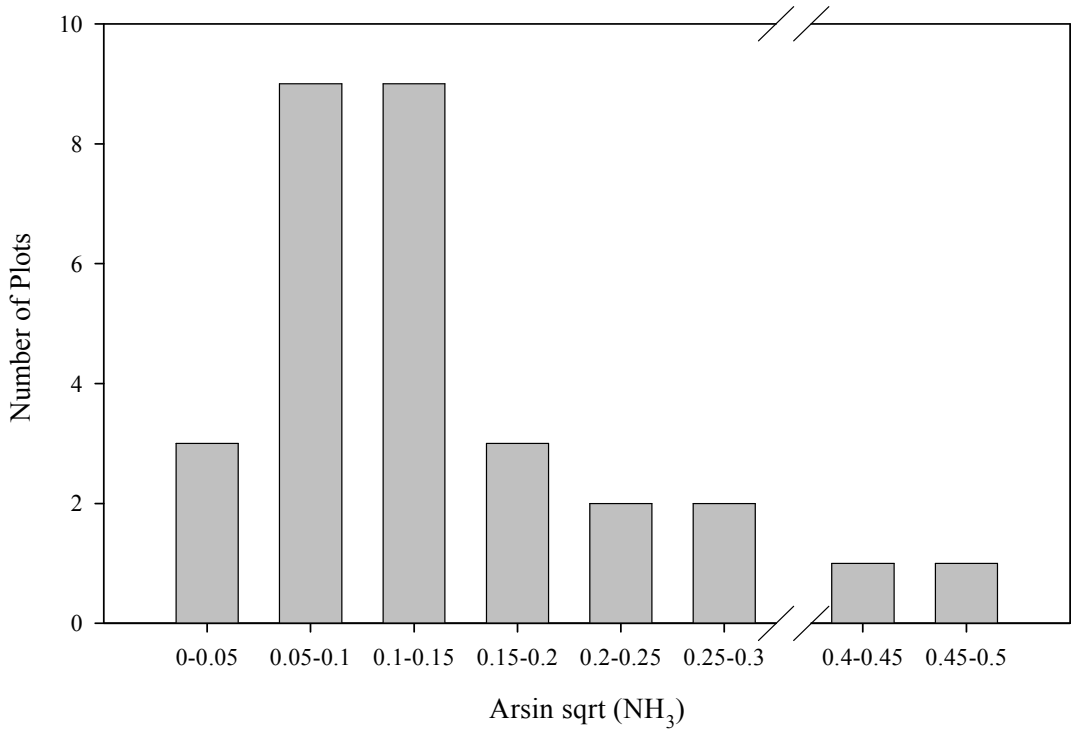



**Figure 2.23. The distribution of the arcsine of the square root transformation of $NH_3$ for plots at the two marsh sites on sample date 8/24/04.**

*Fourth root of concentration*

The fourth root of the concentration is similar to both the square root and arcsine of the square root transformations, in that it improves normality and decreases the range of the distribution. Equation 12 shows the process taken to transform the dependent data and Figure 2.24 illustrates the transformation distribution.

$$Conc_{4\ root} = (Conc)^{1/4} \qquad \text{Equation 12}$$

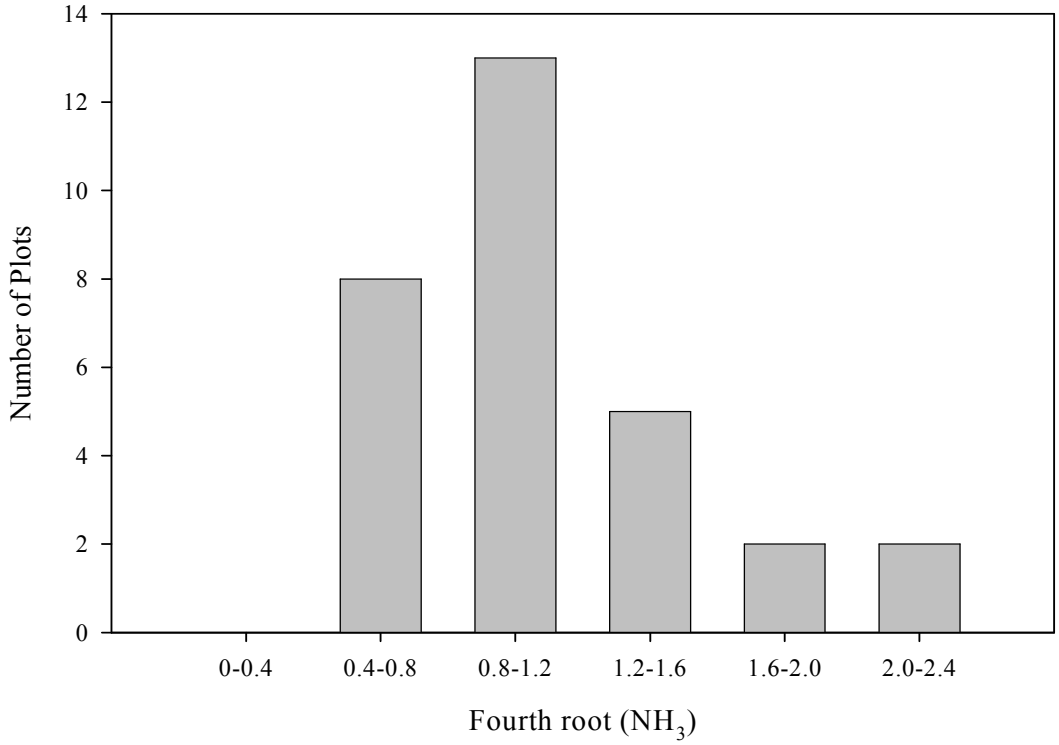



**Figure 2.24. An example of the distribution of the fourth root transformation of $NH_3$ for plots at the two marsh sites on sample date 8/24/04**

*Vegetation component transformations*

Vegetation component transformations included the log of vegetation cover, the square root of cover, arcsine of the square root of cover, and the fourth root of cover. The untransformed vegetation component data were not as skewed as the water quality data, although the transformations did improve normality.

*Summary of transformations*

Table 2.3 summarizes all reflectance transformations used. Tables 2.4 and 2.5 summarize the water quality transformations and vegetation component transformations performed on the data, respectively.

**Table 2.3. Summary of spectral transformations.**

| Spectral Transformations | |
|---|---|
| **Untransformed** | All wavebands used, no transformations |
| **Truncated spectra** | Wavebands 400-950nm used |
| **Normalized spectra** | Each waveband divided by waveband 410 (Reflectance/R410) |
| **Transform 1/R** | One over each waveband |
| **Log R** | Log of each waveband |
| **Norris 1st Derivative** | 1st derivative of the reflectance curve by the Norris algorithm |
| **Norris 1st Derivative, avg 5** | 1st deriv. of the reflectance curve, Norris algorithm, smoothing factor = 5 |
| **Norris 1st Derivative, avg 10** | 1st deriv. of the reflectance curve, Norris algorithm, smoothing factor = 10 |
| **Golay 1st Derivative** | 1st deriv. of the reflectance curve by the S. Golay algorithm |
| **Golay 1st Derivative, avg 5** | 1st deriv. of the reflectance curve, S. Golay algorithm, smoothing factor = 5 |
| **Golay 1st Derivative, avg 10** | 1st deriv.of the reflectance curve, S. Golay algorithm, smoothing factor = 10 |
| **Golay 2nd Derivative, avg 10** | 2nd deriv. of the reflectance curve, S. Golay algorithm, smoothing factor = 10 |
| **MSC Transformation** | Multiplicative scatter correction reduces multiplicative and additive effects |
| **Absorbance Transformation** | Converting reflectance units to absorbance units |
| **Kubelka-Munk Transformation** | Converting reflectance units to Kubelka-Munk absorbance units |

**Table 2.4. Summary of water quality transformations.**

| Water Quality Data Transformations | |
|---|---|
| **Untransformed** | Water quality data as measured |
| **Log (Conc)** | Log of each water quality concentration |
| **Square root (Conc)** | Square root of each water quality concentration |
| **Arcsine sqrt (Conc)** | Arcsine of the square root of each concentration |
| **4th root (Conc)** | Fourth root of each concentration |

**Table 2.5. Summary of vegetation transformations.**

| Vegetation Data Transformations | |
|---|---|
| **Untransformed** | Vegetation data as measured |
| **Log (Veg)** | Log of vegetation data |
| **Square root (Veg)** | Square root of vegetation data |
| **Arcsine sqrt (Veg)** | Arcsine of the square root of vegetation data |
| **4th root Veg** | Fourth root of vegetation data |

# Chapter 3: Results

The results chapter reports on the seasonal dynamics of marsh water quality, vegetation composition, and canopy reflectance. The effects of nitrogen fertilization on water quality and species, analyzed with ANOVA, are also reported. Partial least squares (PLS) models for water quality, leaf nitrogen, and vegetation composition predictions are included, as well as a comparison of significant spectral bands detected in the PLS models and selected during ANOVA.

## *3.1 Marsh Water Quality*

The addition of nitrogen as urea increased the ammonia, nitrate, and total nitrogen concentrations in the sub-surface water, particularly at the *Phragmites*-dominant site for the majority of the 2004 season (June – August). Total phosphorus concentrations did not change with nitrogen application. The effects of nitrogen as urea on sub-surface nutrients over the 2004 growing season are illustrated in section 3.1.1, and analyzed in sections 3.1.2 – 3.1.5.

### *3.1.1 Seasonal dynamics of sub-surface nutrients*

Ammonia, nitrate, total phosphorus, and total nitrogen sub-surface water concentrations fluctuated throughout the growing season, with each treatment yielding a different seasonal pattern of concentration. Figure 3.1.1 shows the mean ammonia concentrations of sub-surface water for each nitrogen treatment during the 2004 growing season. In general the highest urea application generated the highest ammonia concentration. However N100 had the second highest ammonia concentration until 7/19/04. Most treatments increased in ammonia concentration

early in the season, peaked in mid- to late-June, then decreased slowly through 9/21/04, as expected. Ambient conditions, predictably, remained fairly constant at background ammonia levels of around 1 mg-N/L. Surprisingly, N200/1D was also constant throughout the season at levels only slightly above ambient conditions at around 2 mg-N/L.

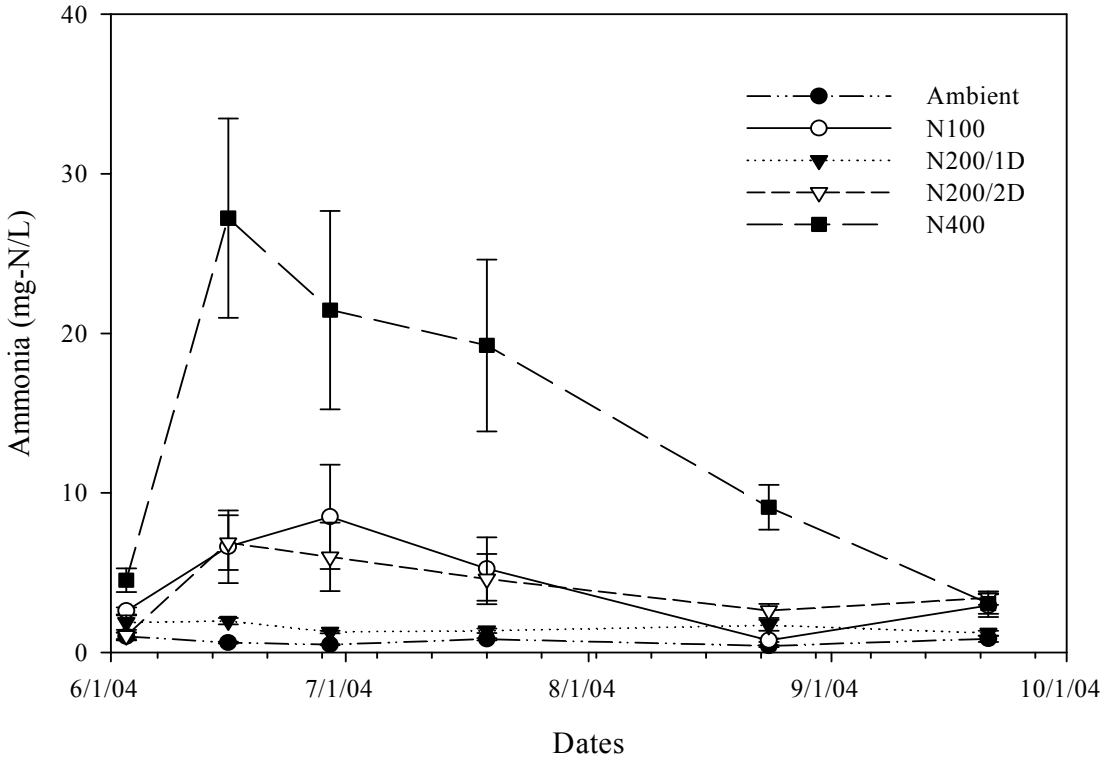



**Figure 3.1.1. Mean and standard errors of ammonia concentrations by urea treatment at the two marsh sites during the 2004 growing season.**

The simulated model for nitrogen release over time developed by Tilley et al. (2004) (Figure 3.1.2) graphically fits the observed concentrations in my study (Figure 3.1.1). N400 increased quickly in both the observed and predicted model, while N200/2D also peaked early before slowly declining through the remaining season.

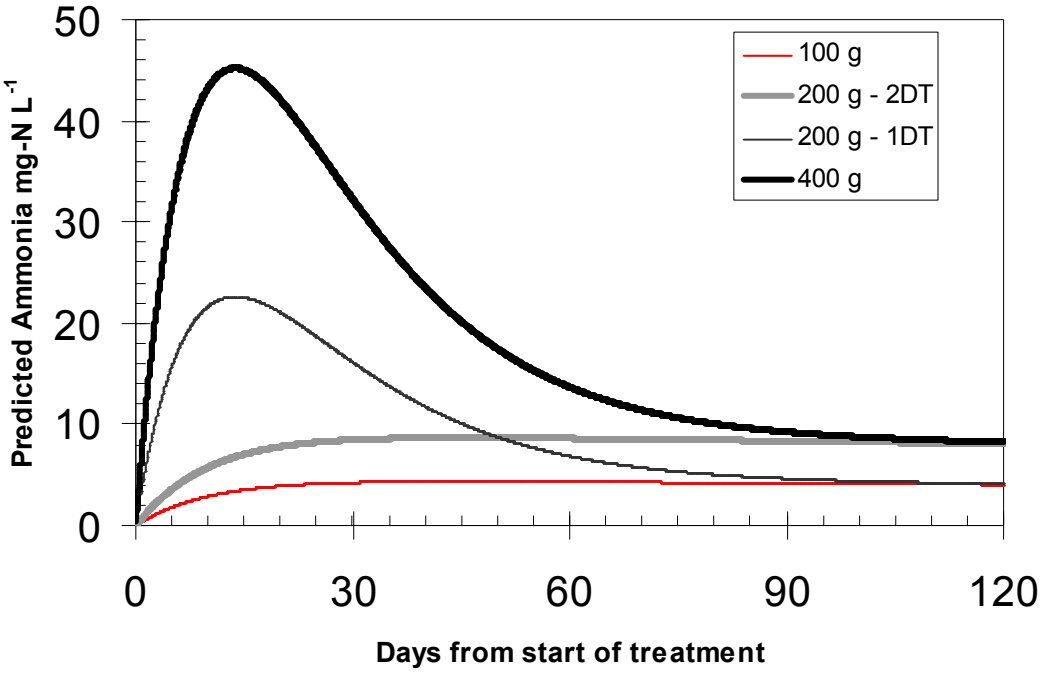



**Figure 3.1.2 Predicted sub-surface water ammonia levels in marsh experimental plots based on a simulation model developed and calibrated on experiments with dialysis tubes in the laboratory (Tilley et al., 2004).**

The addition of nitrogen increased nitrate concentrations in sub-surface water during the 2004 growing season (Figure 3.1.3). N400 had a higher nitrate concentration than other treatments until it decreased sharply after its peak on 7/19/04. Ambient conditions were fairly uniform across the 2004 season, remaining between 1.0 and 2.0 mg-N/L nitrate. N100 steadily increased after the 6/29/04 sample date.

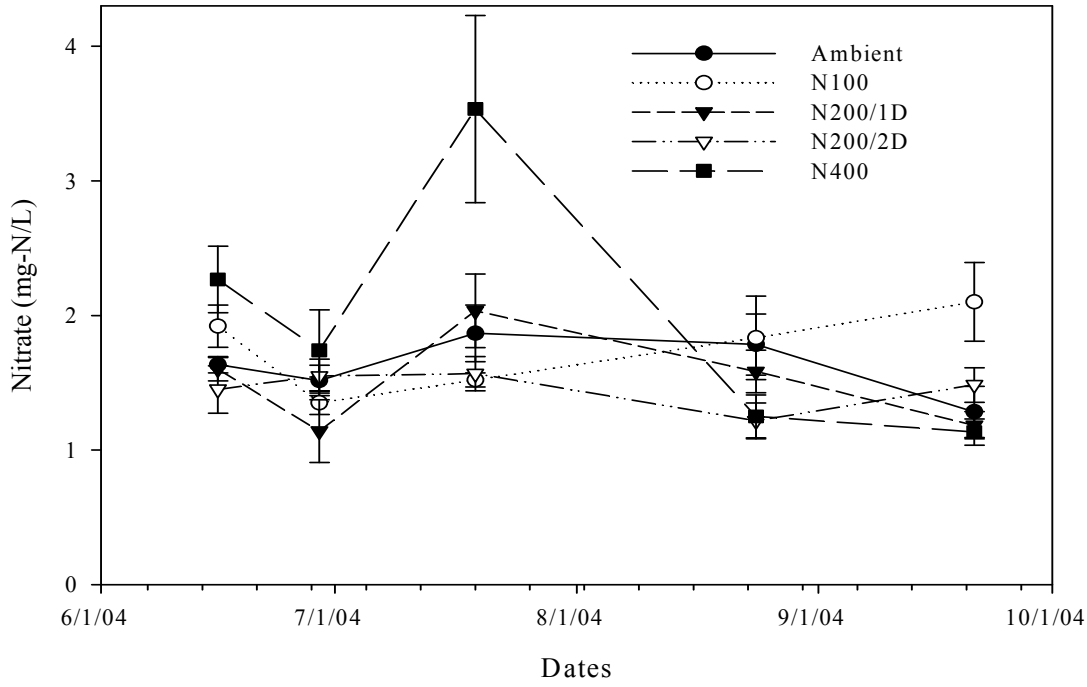



**Figure 3.1.3. Mean and standard errors of nitrate concentration by urea treatment at the two marsh sites during the 2004 growing season.**

Figure 3.1.4 displays mean total phosphorus concentrations of sub-surface water in both marsh sites for each nitrogen treatment during the 2004 growing season. Although N200/2D began with the highest total phosphorus concentration on 6/16/04, all treatments fell into the range of 0.0 – 0.4 mg-P/L by the end of June, and remained in that range through the end of September.

As for total nitrogen concentrations over time, the highest nitrogen treatment produced the highest total nitrogen for the 2004 season, even on 7/19/04 when N400 dropped to about 15 mg - N/L from its average 30 mg - N/L (Figure 3.1.5). Ambient nitrogen conditions hovered slightly above 10 mg - N/L all summer, while N200/1D and N200/2D increased in total nitrogen concentration after 7/19/04.

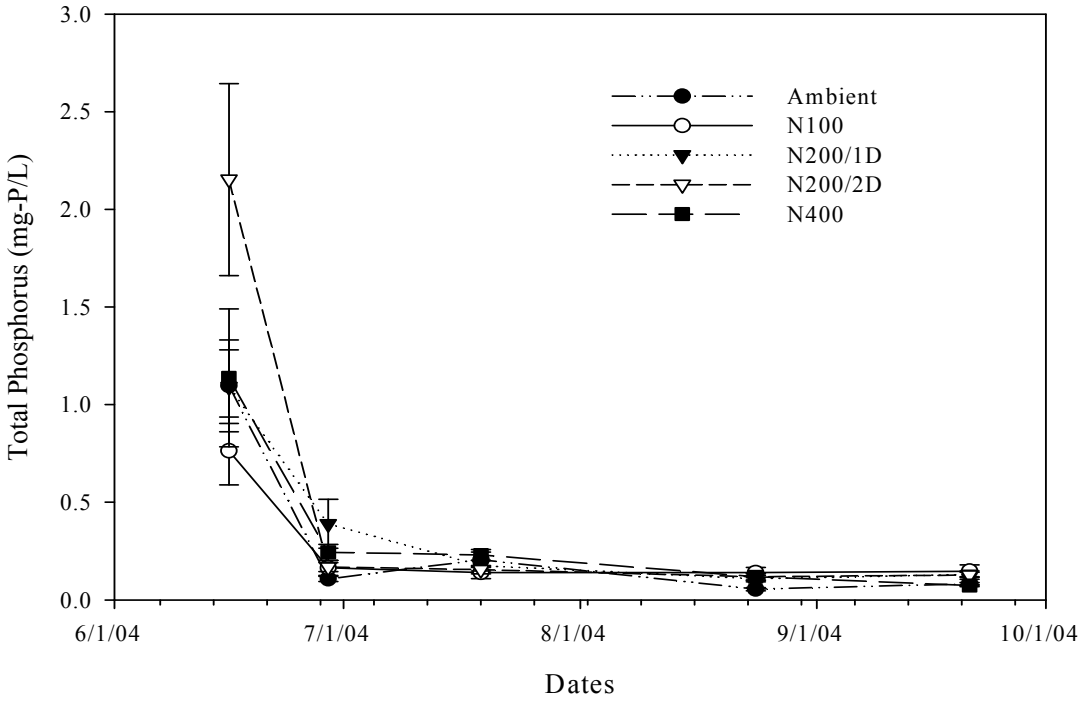



**Figure 3.1.4. Mean and standard errors of total phosphorus concentration by urea treatment at the two marsh sites during the 2004 growing season.**

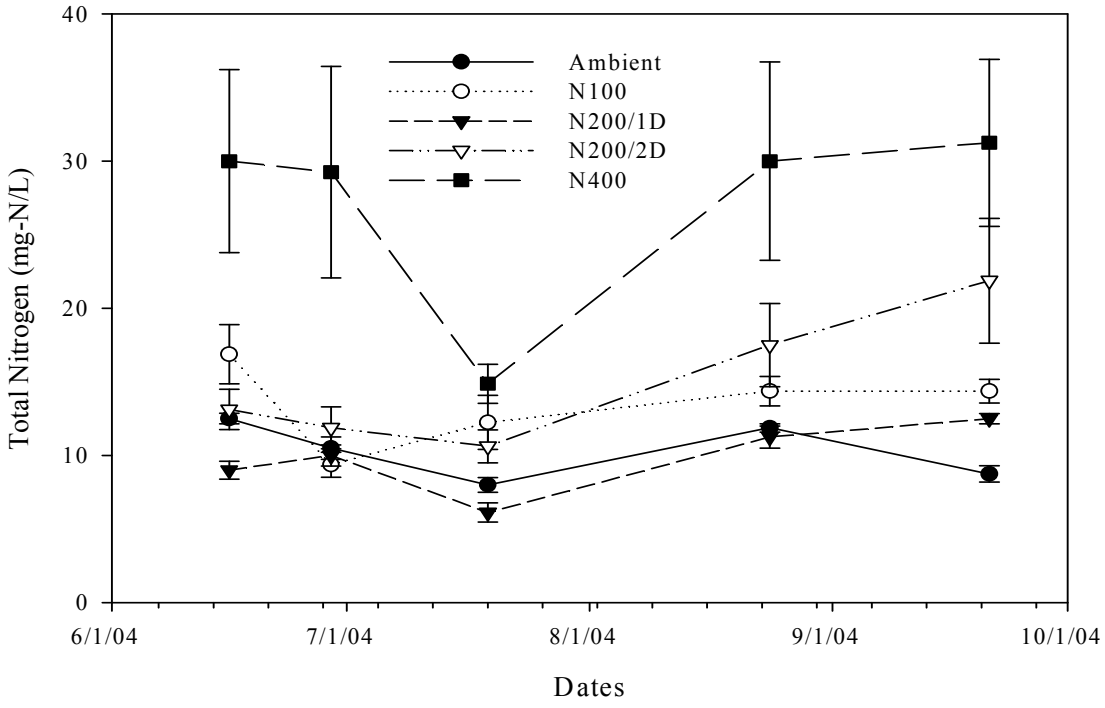



**Figure 3.1.5. Mean and standard errors of total nitrogen concentrations by urea treatment at the two marsh sites during the 2004 growing season.**

Mean ammonia, nitrate, and total phosphorus sub-surface water concentrations during the 2005 growing season are plotted in Figure 3.1.6. In the summer of 2005, ambient ammonia concentrations decreased, as did N200/2D, while all other treatments increased in ammonia. Nitrate concentration decreased for all treatments during the 2005 summer.

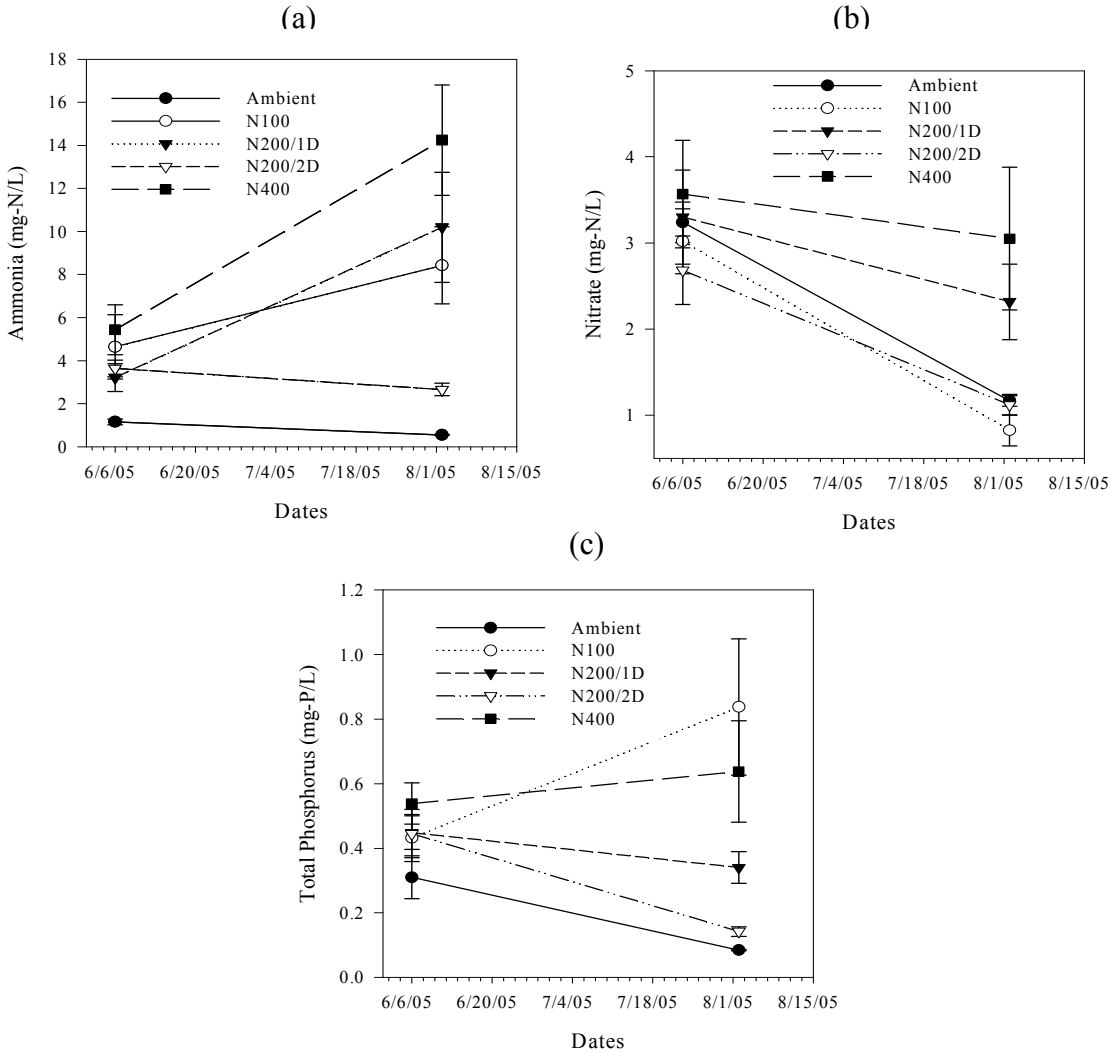



**Figure 3.1.6. Mean and standard errors of (a) ammonia, (b) nitrate, and (c) total phosphorus concentrations by urea treatment at the two marsh sites during the 2005 growing season.**

*3.1.2 Fertilization and Site Effects on $NH_3$*

A repeated measures analysis of variance (ANOVA) was conducted on all water quality nutrients to determine the significance of time and its interaction with nitrogen treatment and site effects, before main effects of nitrogen were considered.

Ammonia sub-surface water concentrations increased with the addition of nitrogen fertilization for the majority of the growing season (June – August) at both sites (Figures 3.1.7 and 3.1.8). Upon analysis, a strong time effect interfered with site and treatment effects (Tables 3.1.1 and 3.1.2), suggesting that nitrogen treatment effect be analyzed on each sample date (Table 3.1.3). Site effects interacted with nitrogen effects for several 2004 dates, but on 6/16/04 and 8/24/04, nitrogen treatment affected ammonia concentrations.

**Table 3.1.1. Repeated measures ANOVA model for 2004 $NH_3$ concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 1139.10 | 1 | 1139.10 | 4.14 | 0.058 |
| Trt | 5414.90 | 4 | 1353.72 | 4.92 | 0.008 |
| Site * Trt | 4518.07 | 4 | 1129.52 | 4.10 | 0.017 |
| Error | 4681.88 | 17 | 275.40 | | |
| Time | 1682.02 | 5 | 336.40 | 5.40 | 0.000 |
| Time * Site | 512.07 | 5 | 102.41 | 1.64 | 0.157 |
| Time * Trt | 3062.82 | 20 | 153.14 | 2.46 | 0.002 |
| Time * Site * Trt | 3118.66 | 20 | 155.93 | 2.50 | 0.002*** |
| Error (time) | 5296.02 | 85 | 62.31 | | |

**Table 3.1.2 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for $NH_3$. *** <0.01, ** < 0.05, * < 0.10. PD site = *Phragmites*-dominant site; PA site = *Phragmites*-absent site**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 8093.40 | 4 | 2023.35 | 4.89 | 0.027 |
| | Time | 1848.90 | 5 | 369.78 | 4.28 | 0.003 |
| | Time * Trt | 4832.07 | 20 | 241.60 | 2.80 | 0.003*** |
| | Error | 3308.61 | 8 | 413.58 | | |
| PA site | Trt | 583.57 | 4 | 145.89 | 0.96 | 0.476 |
| | Time | 1848.90 | 5 | 369.78 | 4.28 | 0.003 |
| | Time * Trt | 4832.07 | 20 | 241.60 | 2.80 | 0.003*** |
| | Error | 1373.27 | 9 | 152.59 | | |

**Table 3.1.3. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for $NH_3$. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/3/2004 | Trt | 25.43 | 4 | 6.36 | 5.10 | 0.005 |
| | Site | 52.80 | 1 | 52.80 | 42.40 | 0.000 |
| | Trt*Site | 24.02 | 4 | 6.01 | 4.82 | 0.007*** |
| | Error | 24.91 | 20 | 1.25 | | |
| 6/16/2004 | Trt | 2725.52 | 4 | 681.38 | 2.36 | 0.090* |
| | Site | 212.01 | 1 | 212.01 | 0.73 | 0.402 |
| | Trt*Site | 1145.47 | 4 | 286.37 | 0.99 | 0.436 |
| | Error | 5482.44 | 19 | 288.55 | | |
| 6/29/2004 | Trt | 2159.96 | 4 | 539.99 | 2.77 | 0.059 |
| | Site | 483.54 | 1 | 483.54 | 2.48 | 0.132 |
| | Trt*Site | 2842.42 | 4 | 710.61 | 3.65 | 0.024** |
| | Error | 3502.85 | 18 | 194.60 | | |
| 7/19/2004 | Trt | 1354.41 | 4 | 338.60 | 2.08 | 0.122 |
| | Site | 363.73 | 1 | 363.73 | 2.23 | 0.151 |
| | Trt*Site | 1689.34 | 4 | 422.34 | 2.59 | 0.068* |
| | Error | 3257.54 | 20 | 162.88 | | |
| 8/24/2004 | Trt | 304.59 | 4 | 76.15 | 6.29 | 0.002*** |
| | Site | 45.63 | 1 | 45.63 | 3.77 | 0.066* |
| | Trt*Site | 57.49 | 4 | 14.37 | 1.19 | 0.347 |
| | Error | 242.18 | 20 | 12.11 | | |
| 9/21/2004 | Trt | 33.12 | 4 | 8.28 | 1.22 | 0.332 |
| | Site | 0.20 | 1 | 0.20 | 0.03 | 0.865 |
| | Trt*Site | 37.04 | 4 | 9.26 | 1.37 | 0.280 |
| | Error | 135.26 | 20 | 6.76 | | |

Since time and site both influenced nitrogen effects on ammonia concentrations, nitrogen treatment effects on individual sample dates and marsh sites were then analyzed. When nitrogen effects were investigated with untransformed data, however, sample variances were unequal, so the log transformation of ammonia concentrations was used for analysis.

Time interacted with site and treatment for the log of ammonia data as well (Table 3.1.4). At the *Phragmites*-dominant site, there was a nitrogen*time interaction effect, but at the *Phragmites*-absent site, there was a time effect instead of an interaction effect (Table 3.1.5). When nitrogen and site effects were analyzed on each sample date, site effect was significant for only two dates (6/03/04 and 8/24/04) because several others had site*treatment interactions (Table 3.1.6). Nitrogen treatment had an effect on log ammonia concentrations on 6/16/04 and 8/24/04, which matched sample dates with treatment effects for untransformed data (Table 3.1.3).

**Table 3.1.4. Repeated measures ANOVA model for 2004 Log ($NH_3$) concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 4.90 | 1 | 4.90 | 24.06 | 0.002 |
| Trt | 10.86 | 4 | 2.71 | 13.32 | 0.002 |
| Site * Trt | 2.50 | 3 | 0.83 | 4.10 | 0.057 |
| Error | 1.43 | 7 | 0.20 | | |
| Time | 0.94 | 5 | 0.19 | 3.01 | 0.023 |
| Time * Site | 0.56 | 5 | 0.11 | 1.78 | 0.142 |
| Time * Trt | 1.82 | 20 | 0.09 | 1.45 | 0.162 |
| Time * Site * Trt | 3.11 | 15 | 0.21 | 3.33 | 0.002*** |
| Error (time) | 2.18 | 35 | 0.06 | | |

**Table 3.1.5 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for Log ($NH_3$). *** <0.01, ** < 0.05, * < 0.10. PD site = *Phragmites*-dominant site; PA site = *Phragmites*-absent site**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 14.64 | 4 | 3.66 | 17.58 | 0.002 |
| | Time | 0.29 | 5 | 0.06 | 0.83 | 0.540 |
| | Time * Trt | 4.09 | 20 | 0.20 | 2.91 | 0.004*** |
| | Error | 1.25 | 6 | 0.21 | | |
| PA site | Trt | 6.97 | 4 | 1.74 | 2.60 | 0.108 |
| | Time | 1.97 | 5 | 0.39 | 3.14 | 0.016** |
| | Time * Trt | 3.02 | 20 | 0.15 | 1.20 | 0.297 |
| | Error | 6.04 | 9 | 0.67 | | |

**Table 3.1.6. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for Log ($NH_3$) *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/3/2004 | Trt | 0.65 | 4 | 0.16 | 1.28 | 0.342 |
| | Site | 2.48 | 1 | 2.48 | 19.54 | 0.001*** |
| | Trt*Site | 0.09 | 3 | 0.03 | 0.23 | 0.875 |
| | Error | 1.27 | 10 | 0.13 | | |
| 6/16/2004 | Trt | 5.67 | 4 | 1.42 | 6.79 | 0.001*** |
| | Site | 0.57 | 1 | 0.57 | 2.73 | 0.115 |
| | Trt*Site | 1.49 | 4 | 0.37 | 1.79 | 0.173 |
| | Error | 3.97 | 19 | 0.21 | | |
| 6/29/2004 | Trt | 3.92 | 4 | 0.98 | 4.56 | 0.010 |
| | Site | 0.41 | 1 | 0.41 | 1.89 | 0.186 |
| | Trt*Site | 3.01 | 4 | 0.75 | 3.50 | 0.028** |
| | Error | 3.87 | 18 | 0.21 | | |
| 7/19/2004 | Trt | 2.64 | 4 | 0.66 | 3.41 | 0.028 |
| | Site | 0.93 | 1 | 0.93 | 4.80 | 0.040 |
| | Trt*Site | 2.37 | 4 | 0.59 | 3.07 | 0.040** |
| | Error | 3.87 | 20 | 0.19 | | |
| 8/24/2004 | Trt | 5.97 | 4 | 1.49 | 9.86 | 0.000*** |
| | Site | 0.80 | 1 | 0.80 | 5.31 | 0.032** |
| | Trt*Site | 0.07 | 4 | 0.02 | 0.12 | 0.973 |
| | Error | 3.03 | 20 | 0.15 | | |
| 9/21/2004 | Trt | 1.82 | 4 | 0.46 | 1.99 | 0.136 |
| | Site | 0.14 | 1 | 0.14 | 0.60 | 0.448 |
| | Trt*Site | 1.27 | 4 | 0.32 | 1.39 | 0.275 |
| | Error | 4.59 | 20 | 0.23 | | |

Since the effect of nitrogen treatment on ammonia concentration was sensitive to time and site, nitrogen effects were analyzed on individual dates at each site (Figures 3.1.7 and 3.1.8). At the *Phragmites*-dominant site during the majority of the growing season (June – August), the higher application of urea resulted in higher ammonia concentrations. By the end of the growing season in September, the effect had diminished, but was still distinguishable, especially for the N200/2D treatment. During the second year, reapplication of urea resulted in elevated ammonia levels, although the consistency of the effect was less clear. Sample date 8/02/05 was missing ammonia concentrations for several plots, explaining the lack of a mean for N100 and the high standard errors for N200/1D and N400 (Figure 3.1.7h).

At the *Phragmites*-absent site, the urea fertilization was less conclusive. While there were hints that higher nitrogen application produced higher ammonia, statistically the effect was not detected except for one or two dates (Figure 3.1.8). The dialysis tube may have been punctured or opened at an N100 plot, which would have caused urea to diffuse more quickly than the designed rate, creating a higher log ammonia mean and standard error for N100. On sample dates 6/03/04 and 8/02/05, several ammonia concentrations were missing, accounting for the absent N100 mean (Figure 3.1.8a and 3.1.8h).

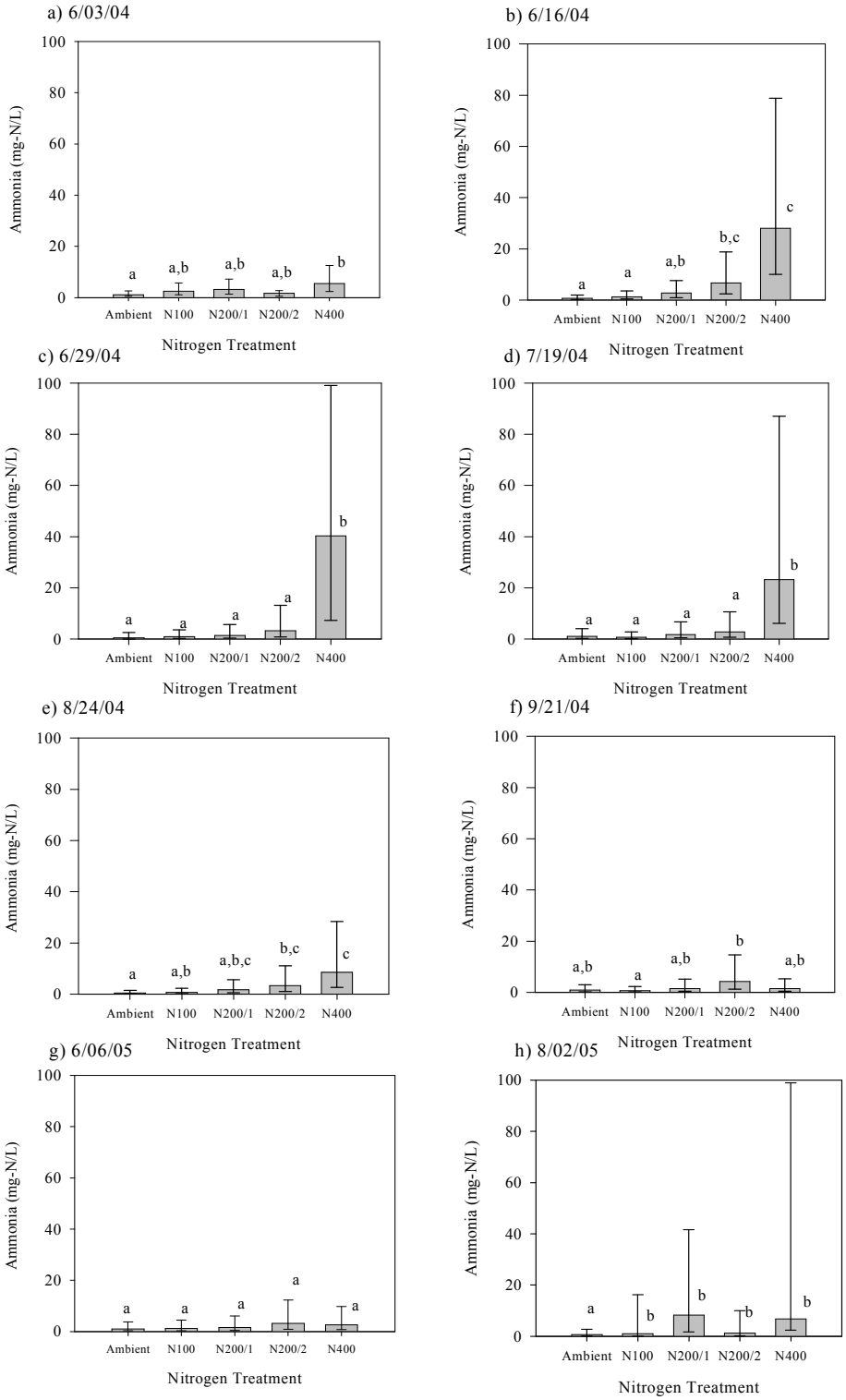



**Figure 3.1.7. Geometric mean of ammonia concentrations (± 95% CL) of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Log of ammonia was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

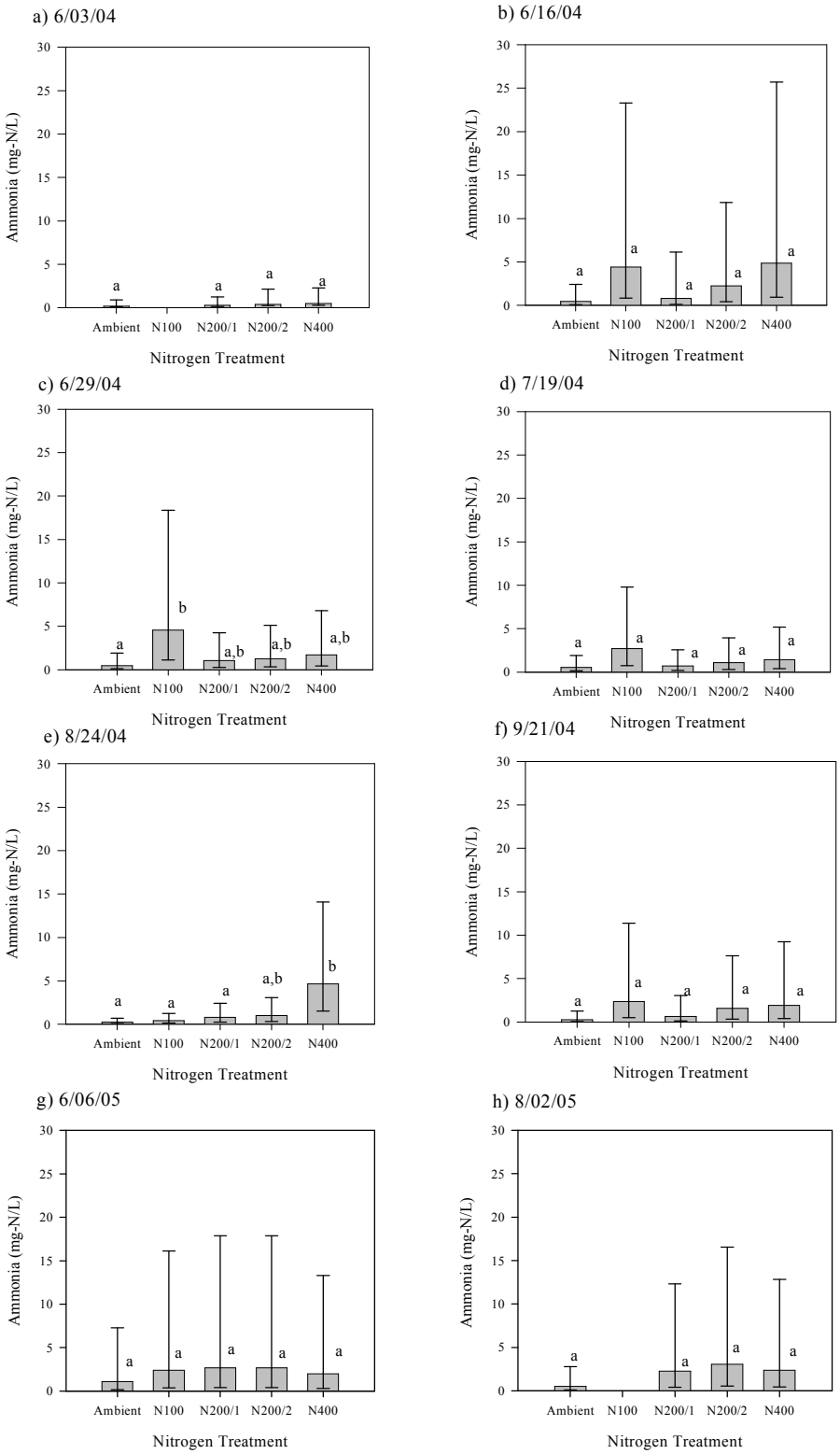



**Figure 3.1.8. Geometric mean of ammonia concentrations (± 95% CL) of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Log ammonia concentration was the dependent variable in the one-way ANOVA model with an LSD contrast. Sample date 8/02/05 had several missing $NH_3$ concentrations.**

*3.1.3 Fertilization and Site Effects on $NO_3$*

Urea application increased nitrate concentrations at the *Phragmites*-dominant site on particular sample dates (Figure 3.1.9), while treatment differences were harder to distinguish at the *Phragmites*-absent site (Figure 3.1.10). Analysis proved that both time and site affected sub-surface nitrate concentrations (Table 3.1.7), so site, then time effects were isolated for the analysis. When individual sites were studied, only the *Phragmites*-absent site displayed a seasonal effect (Table 3.1.8). When individual dates were studied, only the end of the growing season (July – September) displayed a site effect (Table 3.1.9).

**Table 3.1.7. Repeated measures ANOVA model for 2004 $NO_3$ concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 11.58 | 1 | 11.58 | 3.84 | 0.069* |
| Trt | 1.40 | 4 | 0.35 | 0.12 | 0.975 |
| Site * Trt | 2.03 | 4 | 0.51 | 0.17 | 0.951 |
| Error | 45.25 | 15 | 3.02 | | |
| Time | 57.21 | 5 | 11.44 | 20.05 | 0.000*** |
| Time * Site | 5.33 | 5 | 1.07 | 1.87 | 0.110 |
| Time * Trt | 11.32 | 20 | 0.57 | 0.99 | 0.482 |
| Time * Site * Trt | 15.96 | 20 | 0.80 | 1.40 | 0.150 |
| Error (time) | 42.80 | 75 | 0.57 | | |

**Table 3.1.8. ANOVA model: Trt + Time + (Trt*Time) for each marsh site for $NO_3$. *** <0.01, ** < 0.05, * < 0.10. PD site = *Phragmites*-dominant site; PA site = *Phragmites*-absent site**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 2.80 | 4 | 0.70 | 0.11 | 0.977 |
| | Time | 7.45 | 4 | 1.86 | 2.09 | 0.109 |
| | Time * Trt | 20.13 | 16 | 1.26 | 1.41 | 0.207 |
| | Error | 24.97 | 28 | 0.89 | | |
| PA site | Trt | 1.27 | 4 | 0.32 | 0.31 | 0.861 |
| | Time | 3.24 | 4 | 0.81 | 2.95 | 0.035** |
| | Time * Trt | 4.12 | 16 | 0.26 | 0.94 | 0.539 |
| | Error | 8.78 | 32 | 0.27 | | |

**Table 3.1.9. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for $NO_3$. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/16/2004 | Trt | 2.55 | 4 | 0.64 | 0.84 | 0.520 |
| | Site | 1.57 | 1 | 1.57 | 2.06 | 0.168 |
| | Trt*Site | 1.63 | 4 | 0.41 | 0.53 | 0.713 |
| | Error | 13.72 | 18 | 0.76 | | |
| 6/29/2004 | Trt | 1.01 | 4 | 0.25 | 0.26 | 0.898 |
| | Site | 1.73 | 1 | 1.73 | 1.81 | 0.198 |
| | Trt*Site | 2.48 | 4 | 0.62 | 0.65 | 0.637 |
| | Error | 15.35 | 16 | 0.96 | | |
| 7/19/2004 | Trt | 18.49 | 4 | 4.62 | 1.59 | 0.215 |
| | Site | 16.13 | 1 | 16.13 | 5.56 | 0.029** |
| | Trt*Site | 17.87 | 4 | 4.47 | 1.54 | 0.229 |
| | Error | 58.05 | 20 | 2.90 | | |
| 8/24/2004 | Trt | 2.01 | 4 | 0.50 | 0.46 | 0.765 |
| | Site | 8.97 | 1 | 8.97 | 8.17 | 0.010** |
| | Trt*Site | 1.65 | 4 | 0.41 | 0.38 | 0.824 |
| | Error | 21.96 | 20 | 1.10 | | |
| 9/21/2004 | Trt | 3.73 | 4 | 0.93 | 1.33 | 0.295 |
| | Site | 5.38 | 1 | 5.38 | 7.64 | 0.012** |
| | Trt*Site | 4.19 | 4 | 1.05 | 1.49 | 0.243 |
| | Error | 14.07 | 20 | 0.70 | | |

Nitrogen effects on nitrate concentrations were then analyzed at individual sites on each sample date in 2004-5 (Figures 3.1.0 and 3.1.10). At the *Phragmites*-dominant site, only two dates displayed a nitrogen effect. Nitrate concentration for N400 was low at the end of the 2004 season and high at the beginning of the 2005 season (Figure 3.1.9). On sample date 8/02/05, several nitrate concentrations were missing and a nitrogen contrast could not be conducted. At the *Phragmites*-absent site, no differences in nitrate concentrations among nitrogen treatments were detected in the 2004-5 growing seasons (Figure 3.1.10).

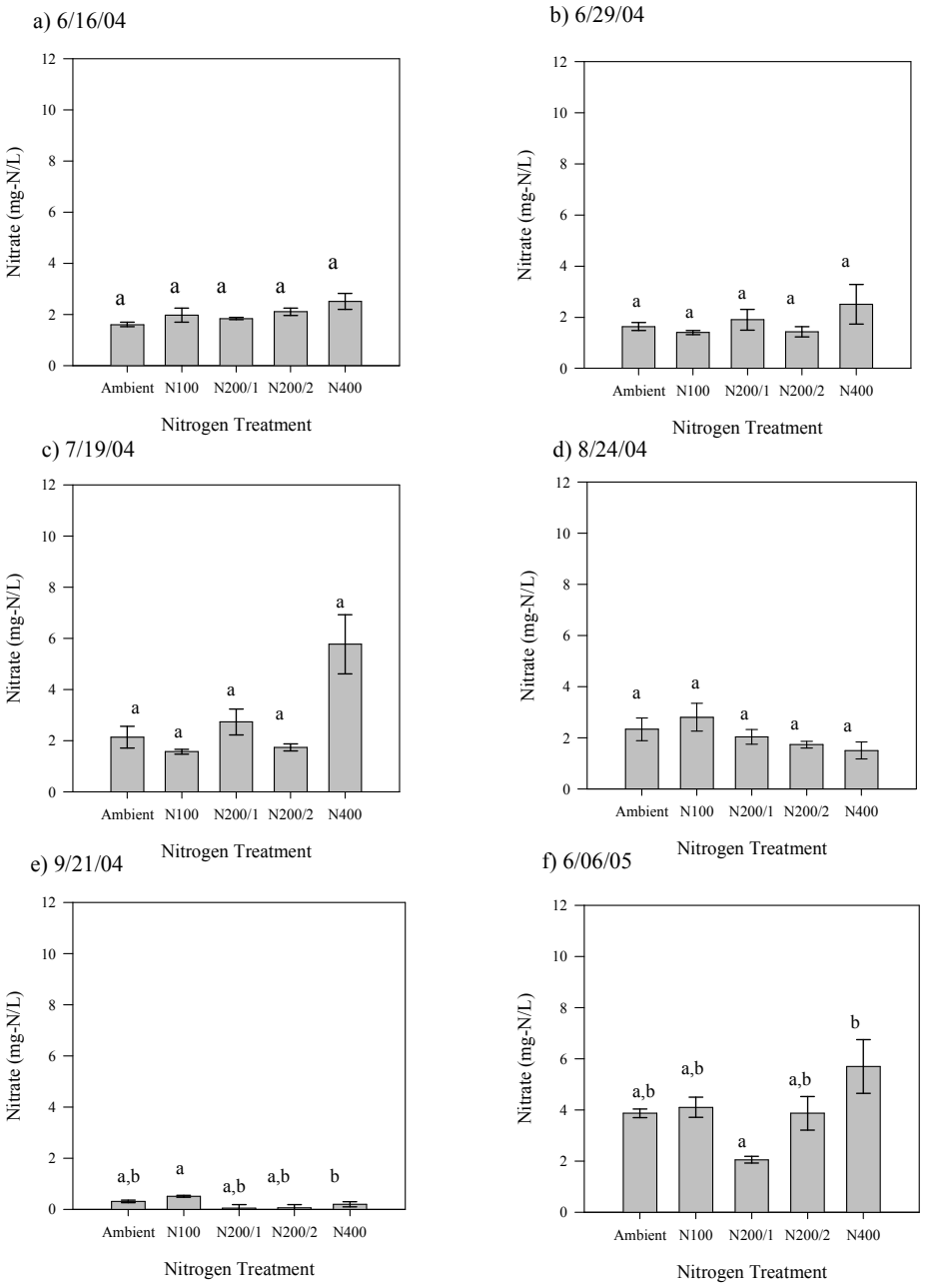



**Figure 3.1.9. Mean nitrate concentrations and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments (p=0.05). Nitrate concentration was the dependent variable in the one-way ANOVA model against treatment with an LSD contrast.**

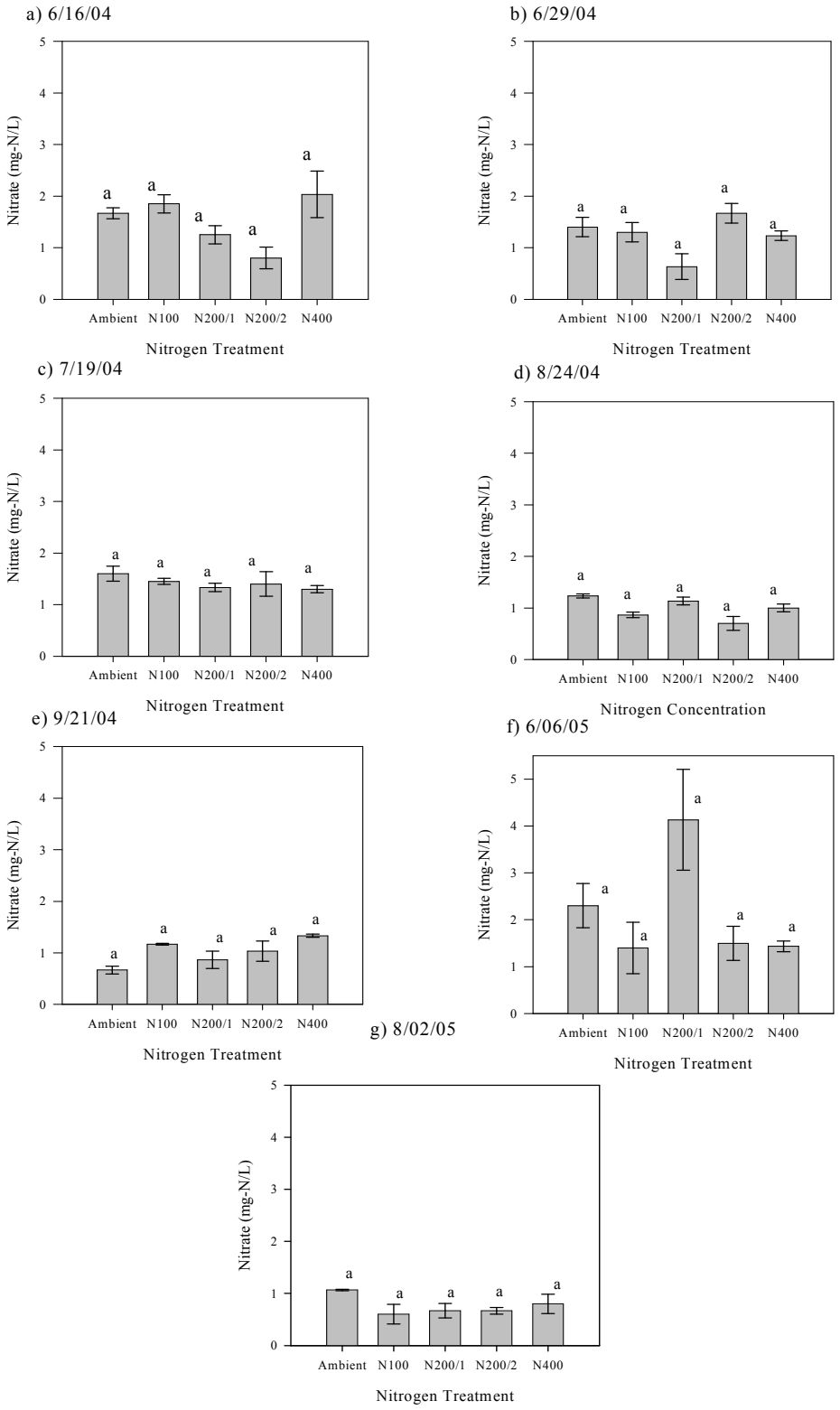



**Figure 3.1.10. Mean nitrate concentrations and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments (p=0.05). Nitrate concentration was the dependent variable in the one-way ANOVA model with an LSD contrast.**

*3.1.4 Fertilization and Site Effects on Total Nitrogen*

The addition of urea increased total nitrogen at the *Phragmites*-dominant site on particular dates (Figure 3.1.11), but did not conclusively change total nitrogen at the *Phragmites*-absent site (Figure 3.1.12). Not only did each site's total nitrogen levels respond differently to additional urea, but there was also a clear seasonal effect at each site (Table 3.1.11). Time had an interaction effect with both site and treatment (Table 3.1.10). Analysis of time, nitrogen, and their interaction at each marsh site found that time was significant at both sites (Table 3.1.11). Analysis of nitrogen, site, and their interaction analyzed on each 2004 sample date found that no site*treatment interaction effect was significant on 6/29/04 and 7/19/04 (Table 3.1.12).

**Table 3.1.10. Repeated measures ANOVA model for 2004 total nitrogen concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 1890.10 | 1 | 1890.10 | 3.08 | 0.097 |
| Trt | 7391.14 | 4 | 1847.78 | 3.01 | 0.048 |
| Site * Trt | 7012.22 | 4 | 1753.05 | 2.86 | 0.056 |
| Error | 10437.41 | 17 | 613.97 | | |
| Time | 6948.40 | 5 | 1389.68 | 18.73 | 0.000 |
| Time * Site | 1431.03 | 5 | 286.21 | 3.86 | 0.003 |
| Time * Trt | 2707.80 | 20 | 135.39 | 1.83 | 0.030 |
| Time * Site * Trt | 2486.99 | 20 | 124.35 | 1.68 | 0.054* |
| Error (time) | 6305.78 | 85 | 74.19 | | |

**Table 3.1.11 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for total nitrogen. *** <0.01, ** < 0.05, * < 0.10. PD site = *Phragmites*-dominant site; PA site = *Phragmites*-absent site**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 12239.13 | 4 | 3059.78 | 2.46 | 0.130 |
| | Time | 6330.03 | 5 | 1266.01 | 9.22 | 0.000*** |
| | Time * Trt | 4220.04 | 20 | 211.00 | 1.54 | 0.122 |
| | Error | 9968.66 | 8 | 1246.08 | | |
| PA site | Trt | 341.02 | 4 | 85.25 | 1.64 | 0.247 |
| | Time | 1854.83 | 5 | 370.97 | 20.47 | 0.000*** |
| | Time * Trt | 428.74 | 20 | 21.44 | 1.18 | 0.312 |
| | Error | 468.75 | 9 | 52.08 | | |

**Table 3.1.12. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for total nitrogen. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/16/2004 | Trt | 1523.83 | 4 | 380.96 | 1.61 | 0.214 |
| | Site | 206.36 | 1 | 206.36 | 0.87 | 0.363 |
| | Trt*Site | 1811.72 | 4 | 452.93 | 1.91 | 0.150 |
| | Error | 4507.03 | 19 | 237.21 | | |
| 6/29/2004 | Trt | 2276.60 | 4 | 569.15 | 3.07 | 0.043 |
| | Site | 843.86 | 1 | 843.86 | 4.55 | 0.047 |
| | Trt*Site | 2533.80 | 4 | 633.45 | 3.42 | 0.030** |
| | Error | 3335.16 | 18 | 185.29 | | |
| 7/19/2004 | Trt | 285.19 | 4 | 71.30 | 2.37 | 0.087 |
| | Site | 56.72 | 1 | 56.72 | 1.89 | 0.185 |
| | Trt*Site | 408.94 | 4 | 102.23 | 3.40 | 0.028** |
| | Error | 601.50 | 20 | 30.08 | | |
| 8/24/2004 | Trt | 1412.81 | 4 | 353.20 | 1.12 | 0.376 |
| | Site | 826.87 | 1 | 826.87 | 2.62 | 0.121 |
| | Trt*Site | 1137.19 | 4 | 284.30 | 0.90 | 0.483 |
| | Error | 6318.75 | 20 | 315.94 | | |
| 9/21/2004 | Trt | 1915.31 | 4 | 478.83 | 1.55 | 0.227 |
| | Site | 480.00 | 1 | 480.00 | 1.55 | 0.227 |
| | Trt*Site | 1005.94 | 4 | 251.48 | 0.81 | 0.532 |
| | Error | 6187.50 | 20 | 309.38 | | |

Mean total nitrogen contrasts did not exhibit homogeneity of sample variances, so a log (base 10) transform was performed on the data to improve variance equality. A time*site interaction, as well as a site*treatment interaction on log of total nitrogen concentrations (Table 3.1.13) demonstrated the need to analyze nitrogen effects at individual sites for each sample date. When nitrogen and time were analyzed at each marsh site, both were significant at the *Phragmites*-dominant site (Table 3.1.14). When nitrogen and site were analyzed on each date, a site effect was observed on 8/24/04 and a nitrogen effect was found on 9/21/04 (Table 3.1.15).

**Table 3.1.13. Repeated measures ANOVA model for 2004 Log (TKN) concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 0.22 | 1 | 0.22 | 1.26 | 0.277 |
| Trt | 2.29 | 4 | 0.57 | 3.28 | 0.036 |
| Site * Trt | 1.76 | 4 | 0.44 | 2.53 | 0.079* |
| Error | 2.96 | 17 | 0.17 | | |
| Time | 0.66 | 4 | 0.16 | 5.43 | 0.001 |
| Time * Site | 0.74 | 4 | 0.18 | 6.10 | 0.000*** |
| Time * Trt | 0.31 | 16 | 0.02 | 0.65 | 0.830 |
| Time * Site * Trt | 0.51 | 16 | 0.03 | 1.06 | 0.413 |
| Error (time) | 2.05 | 68 | 0.03 | | |

**Table 3.1.14 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for Log (TKN). *** <0.01, ** < 0.05, * < 0.10. PD site = *Phragmites*-dominant site; PA site = *Phragmites*-absent site**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 3.27 | 4 | 0.82 | 2.82 | 0.099* |
| | Time | 1.15 | 4 | 0.29 | 9.92 | 0.000*** |
| | Time * Trt | 0.38 | 16 | 0.02 | 0.82 | 0.656 |
| | Error | 0.93 | 32 | 0.03 | | |
| PA site | Trt | 0.31 | 4 | 0.08 | 1.07 | 0.426 |
| | Time | 0.20 | 4 | 0.05 | 1.63 | 0.187 |
| | Time * Trt | 0.44 | 16 | 0.03 | 0.88 | 0.594 |
| | Error | 1.13 | 36 | 0.03 | | |

**Table 3.1.15. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for Log (TKN). *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/16/2004 | Trt | 0.48 | 4 | 0.12 | 2.21 | 0.107 |
| | Site | 0.01 | 1 | 0.01 | 0.10 | 0.757 |
| | Trt*Site | 0.45 | 4 | 0.11 | 2.09 | 0.122 |
| | Error | 1.03 | 19 | 0.05 | | |
| 6/29/2004 | Trt | 0.47 | 4 | 0.12 | 1.60 | 0.217 |
| | Site | 0.16 | 1 | 0.16 | 2.15 | 0.159 |
| | Trt*Site | 0.63 | 4 | 0.16 | 2.12 | 0.120 |
| | Error | 1.33 | 18 | 0.07 | | |
| 7/19/2004 | Trt | 0.25 | 4 | 0.06 | 1.81 | 0.168 |
| | Site | 0.32 | 1 | 0.32 | 9.32 | 0.007 |
| | Trt*Site | 0.46 | 4 | 0.12 | 3.34 | 0.031** |
| | Error | 0.66 | 19 | 0.03 | | |
| 8/24/2004 | Trt | 0.28 | 4 | 0.07 | 1.10 | 0.382 |
| | Site | 0.32 | 1 | 0.32 | 5.06 | 0.036** |
| | Trt*Site | 0.16 | 4 | 0.04 | 0.65 | 0.631 |
| | Error | 1.26 | 20 | 0.06 | | |
| 9/21/2004 | Trt | 0.66 | 4 | 0.16 | 2.32 | 0.092* |
| | Site | 0.08 | 1 | 0.08 | 1.11 | 0.304 |
| | Trt*Site | 0.19 | 4 | 0.05 | 0.66 | 0.627 |
| | Error | 1.41 | 20 | 0.07 | | |

Since the effect of nitrogen treatment on log of total nitrogen concentrations was sensitive to time and site, nitrogen treatment effects were evaluated on individual dates at each site. Mean log total nitrogen concentrations for the *Phragmites*-dominant site showed several nitrogen effects. Specifically N400 produced higher log nitrogen concentrations than other treatments for the majority of the 2004 growing season (Figure 3.1.11). At the *Phragmites*-absent site, N100 had a higher log total nitrogen concentration than other treatments on 6/16/04 and 7/19/04, possibly due to a break in the dialysis tube at one of the N100 plots (Figure 3.1.12a and c).

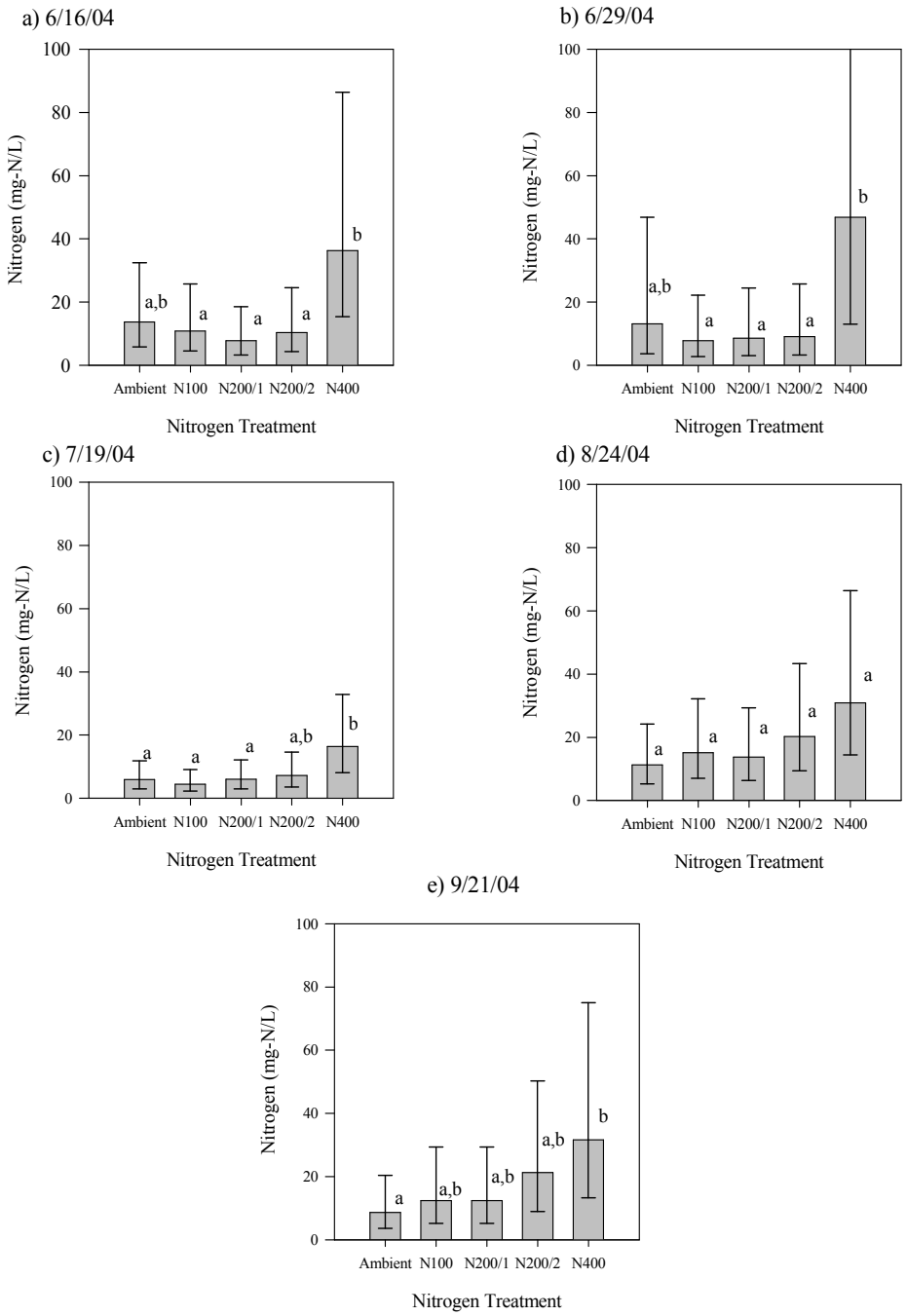



**Figure 3.1.11. Geometric mean of total nitrogen concentrations (± 95% CL) of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments (p=0.05). Log total nitrogen concentration was the dependent variable in the one-way ANOVA model against treatment with an LSD contrast.**

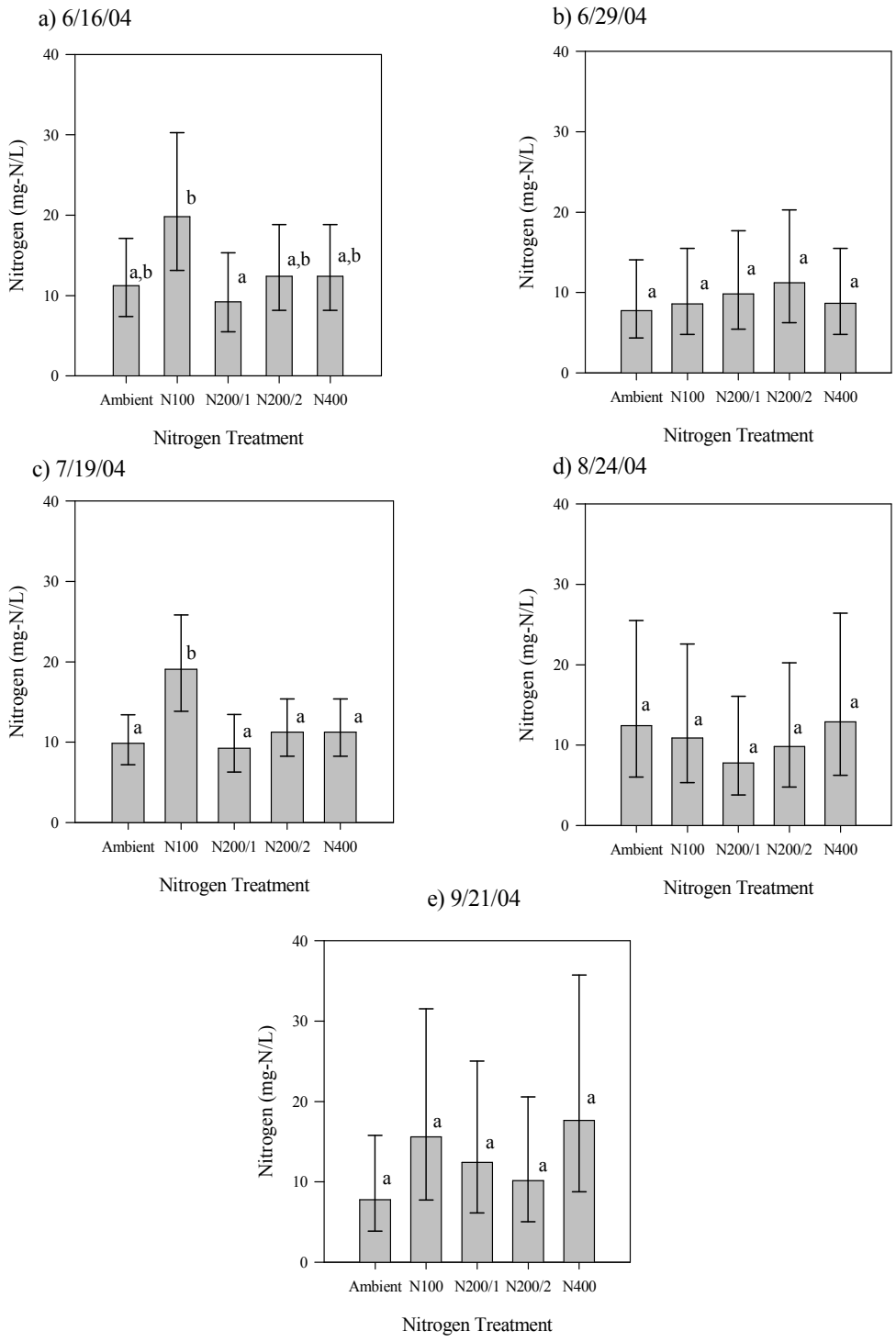



**Figure 3.1.12. Geometric mean of total nitrogen concentrations (± 95% CL) of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments (p=0.05). Log total nitrogen concentration was the dependent variable in the one-way ANOVA model with an LSD contrast.**

*3.1.5 Fertilization and Site Effects on Total Phosphorus*

Addition of nitrogen did not change total phosphorus levels throughout the experimental study period. Time, however, had an effect on phosphorus (Table 3.1.16), so nitrogen and site effects were analyzed on each sample date in 2004-5 (Table 3.1.17). No nitrogen or site effects on total phosphorus were determined on any 2004-5 sample date (Table 3.1.17).

**Table 3.1.16. Repeated measures ANOVA model for 2004 TP concentrations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 0.10 | 1 | 0.10 | 0.14 | 0.716 |
| Trt | 1.90 | 4 | 0.47 | 0.66 | 0.628 |
| Site * Trt | 2.33 | 4 | 0.58 | 0.81 | 0.535 |
| Error | 11.47 | 16 | 0.72 | | |
| Time | 22.72 | 5 | 4.54 | 7.79 | 0.000*** |
| Time * Site | 0.82 | 5 | 0.16 | 0.28 | 0.922 |
| Time * Trt | 8.67 | 20 | 0.43 | 0.74 | 0.769 |
| Time * Site * Trt | 4.26 | 20 | 0.21 | 0.37 | 0.993 |
| Error (time) | 46.65 | 80 | 0.58 | | |

**Table 3.1.17. ANOVA model: Site + Trt + (Site*Trt) at all sample dates for TP. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/3/2004 | Trt | 0.08 | 4 | 0.02 | 0.65 | 0.634 |
| | Site | 0.05 | 1 | 0.05 | 1.86 | 0.188 |
| | Trt*Site | 0.16 | 4 | 0.04 | 1.32 | 0.296 |
| | Error | 0.59 | 20 | 0.03 | | |
| 6/16/2004 | Trt | 6.67 | 4 | 1.67 | 0.49 | 0.746 |
| | Site | 0.31 | 1 | 0.31 | 0.09 | 0.766 |
| | Trt*Site | 4.11 | 4 | 1.03 | 0.30 | 0.875 |
| | Error | 65.21 | 19 | 3.43 | | |
| 6/29/2004 | Trt | 0.27 | 4 | 0.07 | 0.57 | 0.688 |
| | Site | 0.00 | 1 | 0.00 | 0.01 | 0.920 |
| | Trt*Site | 0.51 | 4 | 0.13 | 1.08 | 0.398 |
| | Error | 2.02 | 17 | 0.12 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 7/19/2004 | Trt | 0.03 | 4 | 0.01 | 0.34 | 0.851 |
| | Site | 0.00 | 1 | 0.00 | 0.00 | 0.972 |
| | Trt*Site | 0.19 | 4 | 0.05 | 2.01 | 0.131 |
| | Error | 0.48 | 20 | 0.02 | | |
| 8/24/2004 | Trt | 0.02 | 4 | 0.01 | 0.62 | 0.656 |
| | Site | 0.03 | 1 | 0.03 | 2.74 | 0.113 |
| | Trt*Site | 0.02 | 4 | 0.00 | 0.39 | 0.812 |
| | Error | 0.20 | 20 | 0.01 | | |
| 9/21/2004 | Trt | 0.02 | 4 | 0.01 | 0.74 | 0.578 |
| | Site | 0.02 | 1 | 0.02 | 2.46 | 0.133 |
| | Trt*Site | 0.06 | 4 | 0.02 | 1.89 | 0.151 |
| | Error | 0.17 | 20 | 0.01 | | |

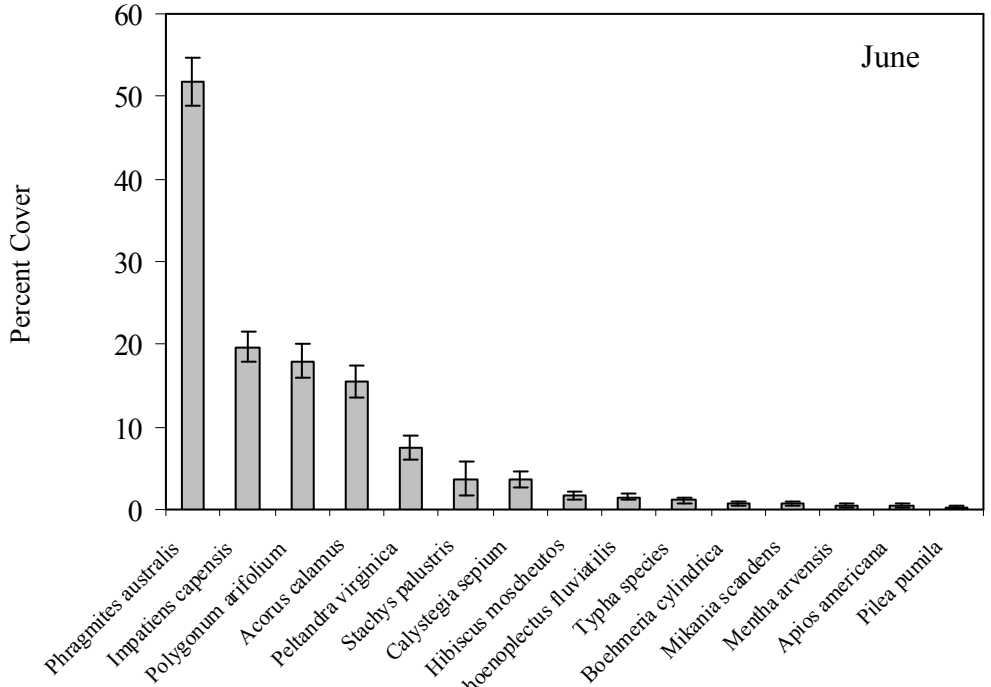
### *3.2 Marsh Vegetation Composition*

Nitrogen fertilization affected species differently. For some species, such as *P. austrlis*, *P. virginica*, *Typha* species, and dead material, cover was low for high additions of nitrogen as urea. Other species, like *A. calamus*, *P. arifolium*, and *I. capensis* had a low cover for a slight addition of nitrogen that increased with high nitrogen fertilization. Both leaf area index and species richness were high for a large addition of nitrogen.

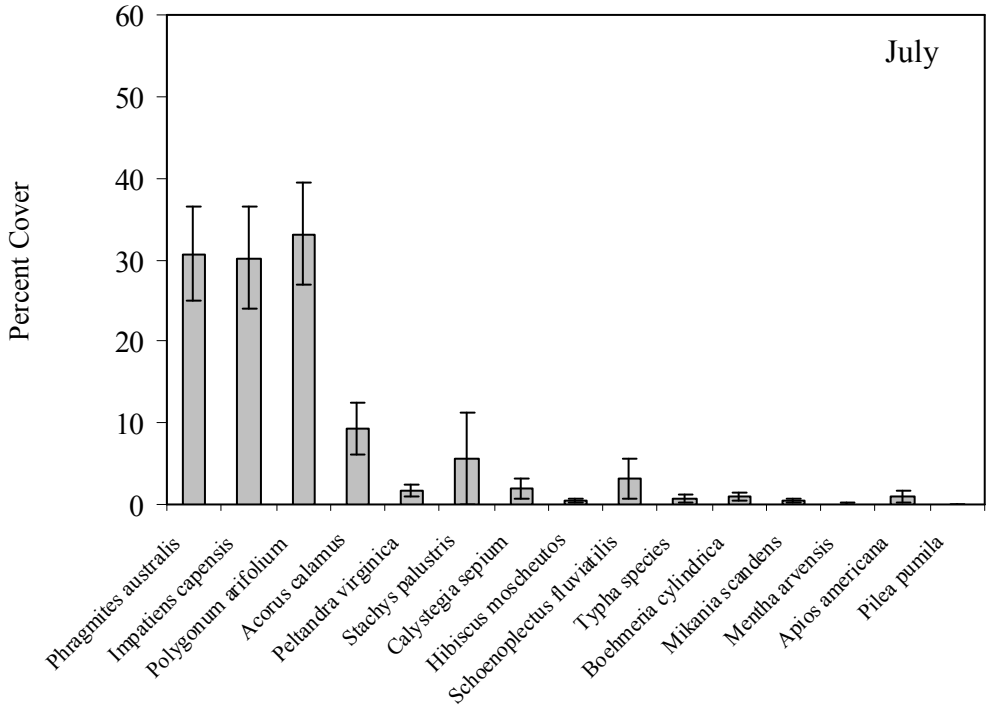
#### *3.2.1 Pattern of dominant species over the growing season at each site*

The vegetation at the tidal freshwater marsh was very diverse, with at least forty species identified during the growing season. Along with a high diversity, the vegetation composition changed seasonally as cover of early dominant species was reduced and minor species became the more widespread. Figure 3.2.1 illustrates the diversity of the *Phragmites*-dominant site and the changes in dominant species as the summer progressed. In June, *Phragmites australis* was clearly the dominant species at the *Phragmites*-dominant site (Figure 3.2.1a), but in July both *Impatiens capensis* and *Polygonum arifolium* had equal percent covers to *P. australis* (Figure 3.2.1b) and by August *P. arifolium* was more prominent than both *P. australis* and *I. capensis* at the site (Figure 3.2.1c). As *P. arifolium* began to senesce in September, *I. capensis* became the dominant species (Figure 3.2.1d). By September, a few species that had minor representation early in the season became more prevalent (~ 10% cover) (Figure 3.2.1d).

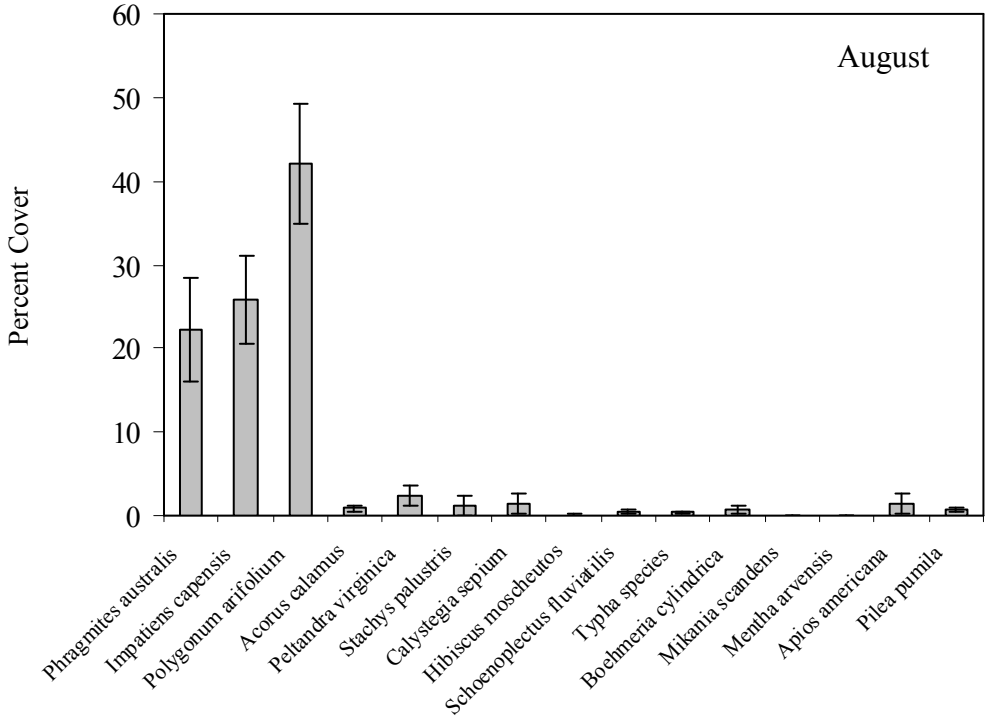
(a)


June
Percent Cover
60
50
40
30
20
10
0
Phragmites australis
Impatiens capensis
Polygonum arifolium
Acorus calamus
Peltandra virginica
Stachys palustris
Calystegia sepium
Hibiscus moscheutos
Schoenoplectus fluviatilis
Typha species
Boehmeria cylindrica
Mikania scandens
Mentha arvensis
Apios americana
Pilea pumila

(b)


July
Percent Cover
60
50
40
30
20
10
0
Phragmites australis
Impatiens capensis
Polygonum arifolium
Acorus calamus
Peltandra virginica
Stachys palustris
Calystegia sepium
Hibiscus moscheutos
Schoenoplectus fluviatilis
Typha species
Boehmeria cylindrica
Mikania scandens
Mentha arvensis
Apios americana
Pilea pumila

(c)




(d)

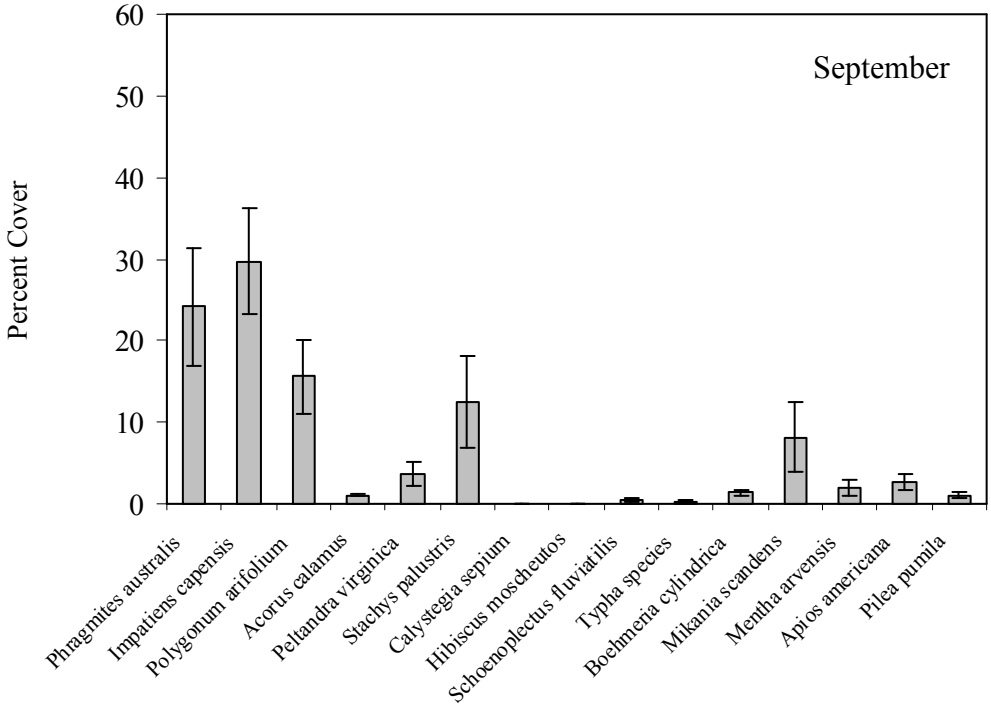
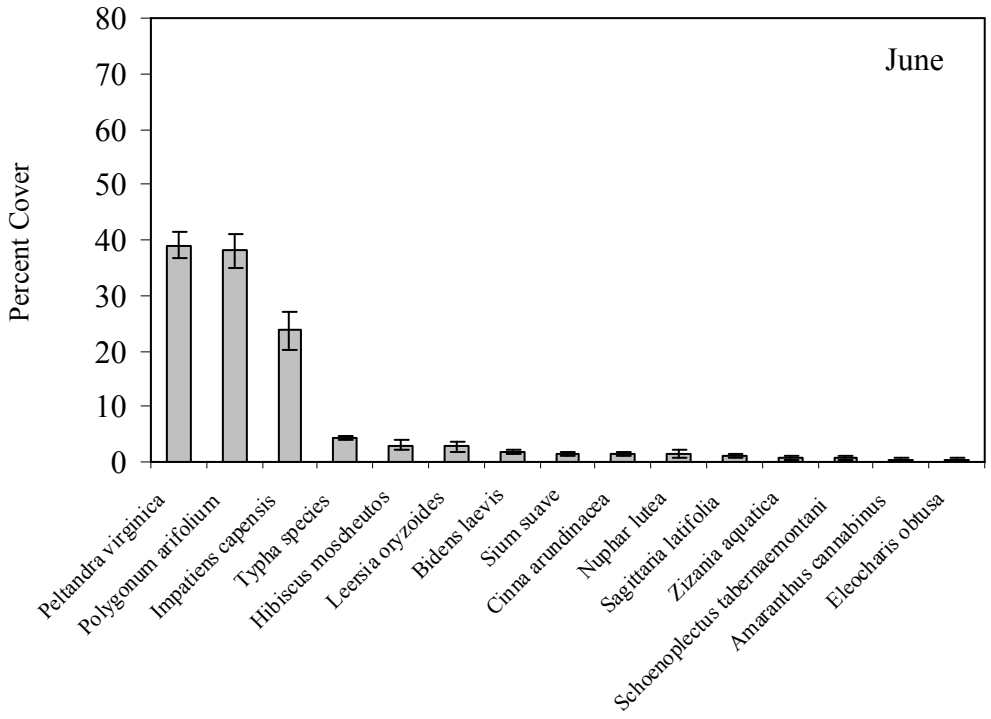


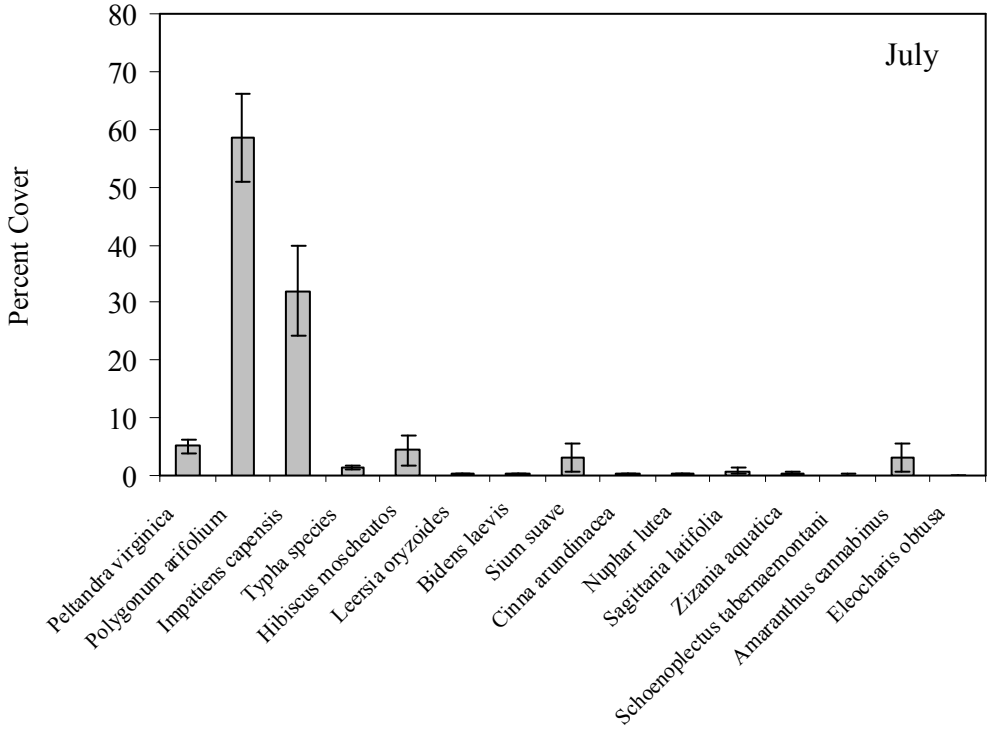

**Figure 3.2.1. Mean percent cover of all species in each plot at the *Phragmites*-dominant site (plots = 15) in (a) June, (b) July, (c) August, and (d) September of 2004.**

Not only did the marsh have high species richness, but each marsh site had a very different vegetation composition. The *Phragmites*-absent site had no *P. australis*, but instead was dominated by *P. virginica* and *P. arifolium* in June (Figure 3.2.2a). In July, *P. virginica* had been out-competed by *P. arifolium* and *I. capensis* (Figure 3.2.2b), and by August, almost every species had been out-competed by *P. arifolium* (Figure 3.2.2c). All species were senescing in September, although *P. arifolium* was still the dominant species at the *Phragmites*-absent site (Figure 3.2.2d).

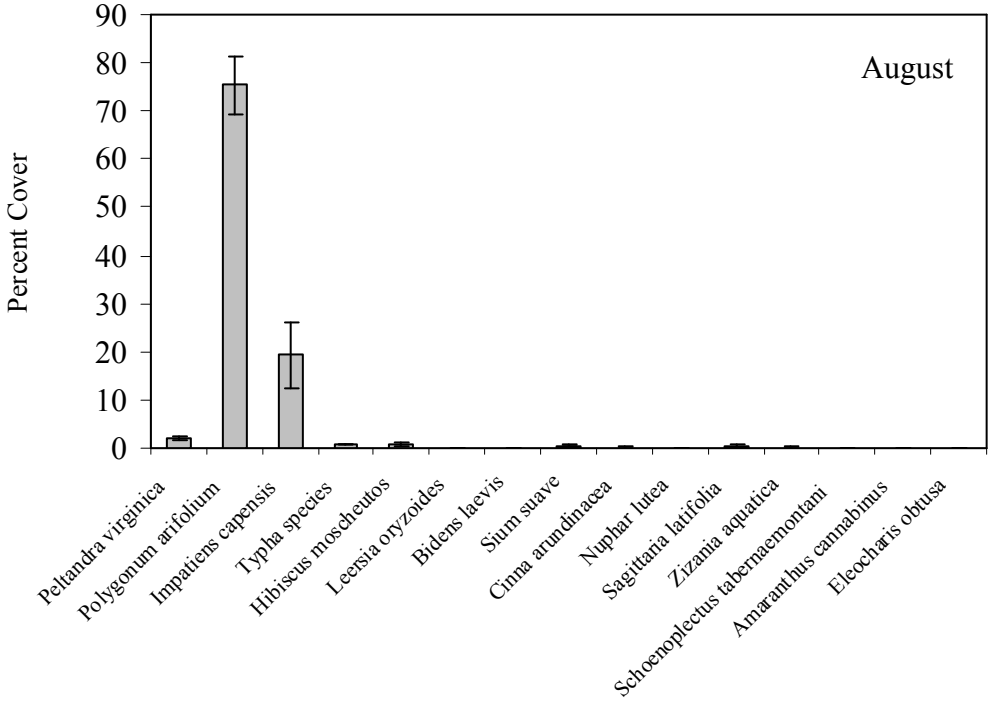
(a)



(b)


July
Percent Cover
80
70
60
50
40
30
20
10
0
Peltandra virginica
Polygonum arifolium
Impatiens capensis
Typha species
Hibiscus moscheutos
Leersia oryzoides
Bidens laevis
Sium suave
Cinna arundinacea
Nuphar lutea
Sagittaria latifolia
Zizania aquatica
Schoenoplectus tabernaemontani
Amaranthus cannabinus
Eleocharis obtusa

(c)


August
Percent Cover
90
80
70
60
50
40
30
20
10
0
Peltandra virginica
Polygonum arifolium
Impatiens capensis
Typha species
Hibiscus moscheutos
Leersia oryzoides
Bidens laevis
Sium suave
Cinna arundinacea
Nuphar lutea
Sagittaria latifolia
Zizania aquatica
Schoenoplectus tabernaemontani
Amaranthus cannabinus
Eleocharis obtusa

(d)

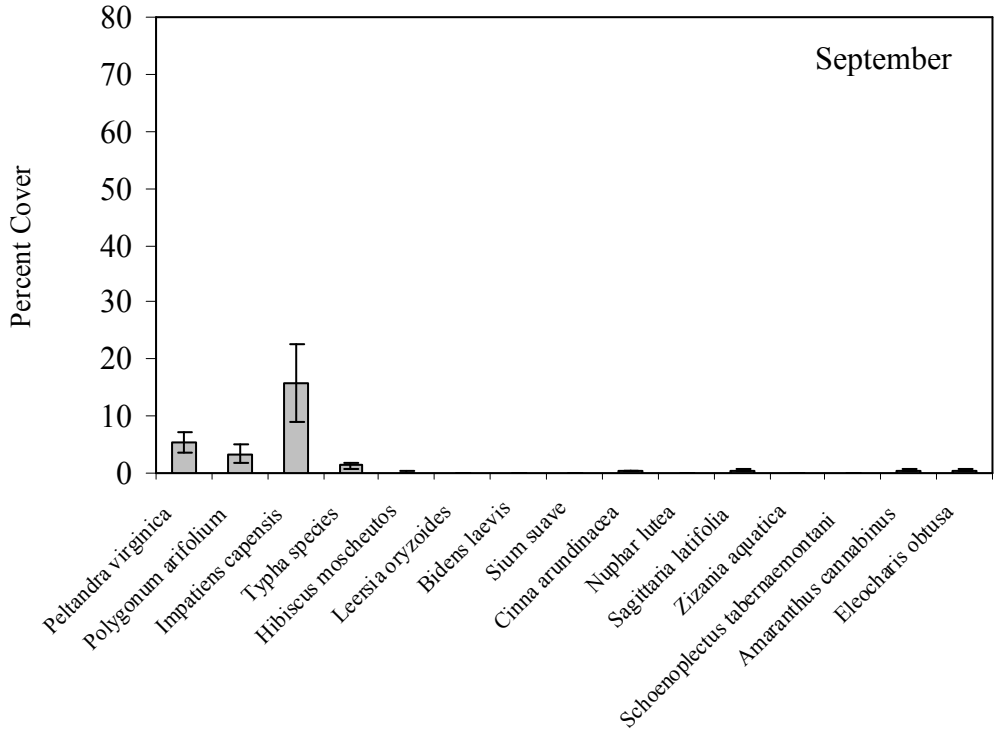


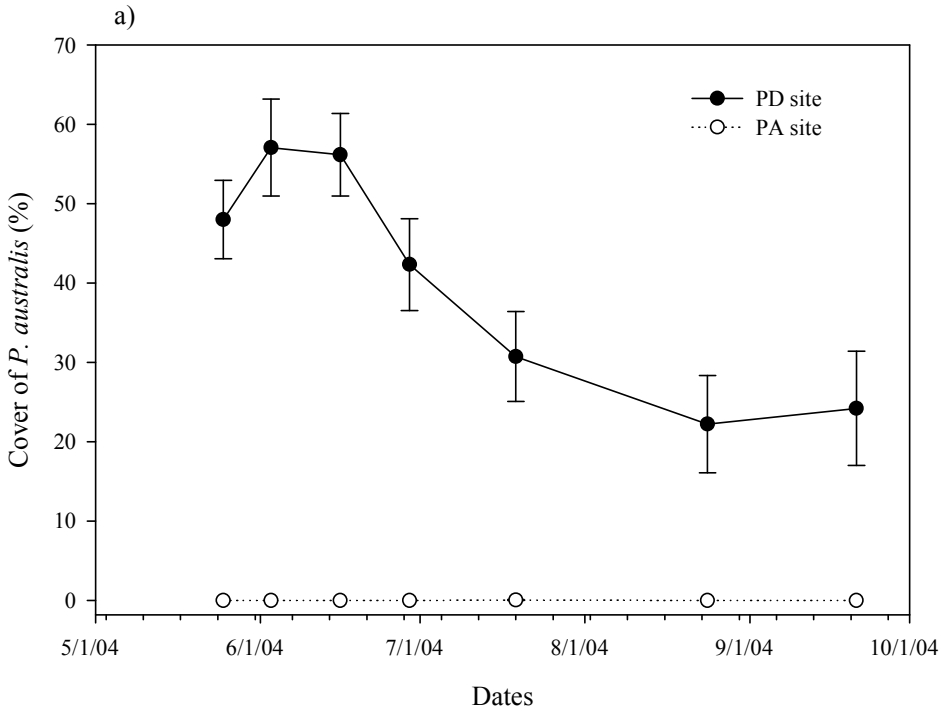

**Figure 3.2.2. Mean percent cover of all species in each plot at the *Phragmites*-absent site (plots = 15) in (a) June, (b) July, (c) August, and (d) September of 2004.**

*3.2.2 Fertilization effects on vegetation cover*

To determine if nitrogen fertilization affected vegetation composition, six prominent species, *Phragmites australis*, *Polygonum arifolium*, *Impatiens capensis*, *Typha* species, *Acorus calamus*, and *Peltandra virginica,* were chosen for analysis of nitrogen treatment effects. These species were in the top four dominant species at each site (see Figures 3.2.1a and 3.2.2a). In addition to analyzing nitrogen effects on species, we analyzed whether nitrogen affected leaf area index, species richness, percent cover of dead material, and species diversity.

*Effects on P. australis*

Evaluation of nitrogen effects on *P. australis* began by determining the effect of site and time on the species. Since the marsh sites were categorized as either dominated by *Phragmites* or devoid of *Phragmites*, there was a clear difference in *P. australis* cover between sites (Figure 3.2.3). The treatment and time effects were evaluated for the *Phragmites*-dominant site, and although no treatment effect was observed, time affected *P. australis* cover (Table 3.2.1), suggesting that nitrogen effects be analyzed on individual sample dates.



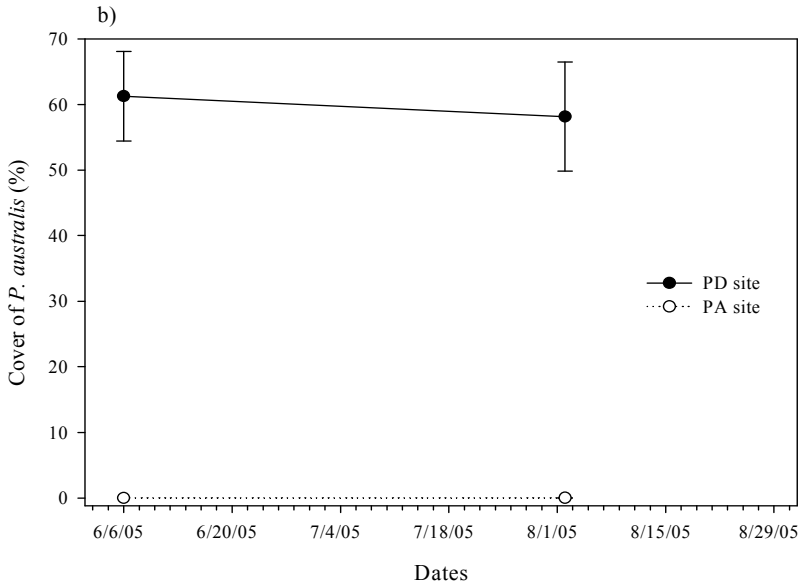
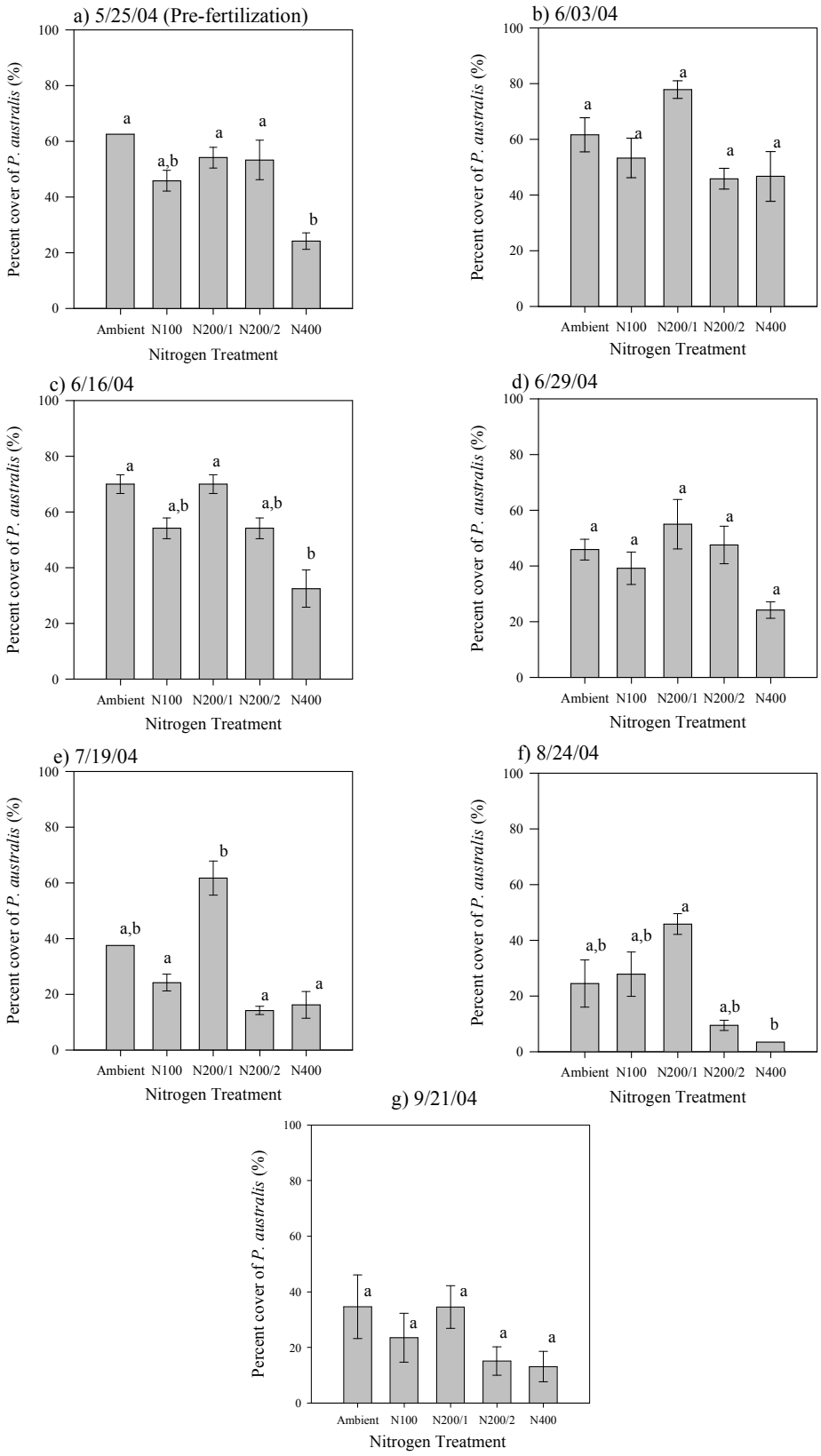



**Figure 3.2.3. Mean percent cover and standard errors of *P. australis* for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.1 ANOVA model: Trt + Time + (Trt*Time) of *P. australis* percent cover for the *Phragmites*-dominant site. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 14340.13 | 4 | 3585.03 | 1.69 | 0.228 |
| | Time | 19097.48 | 6 | 3182.91 | 16.18 | 0.000*** |
| | Time * Trt | 3956.40 | 24 | 164.85 | 0.84 | 0.677 |
| | Error | 11805.40 | 60 | 196.76 | | |

Figure 3.2.4 shows nitrogen effect on *P. australis* percent cover for each sample date in 2004 and 2005 at the *Phragmites*-dominant site. In general throughout the growing season, *P. australis* percent cover was high for medium nitrogen fertilization (N200/1D) (Figure 3.2.4).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of P. australis (%)
Nitrogen Treatment
Ambient
N100
N200/1
N200/2
N400

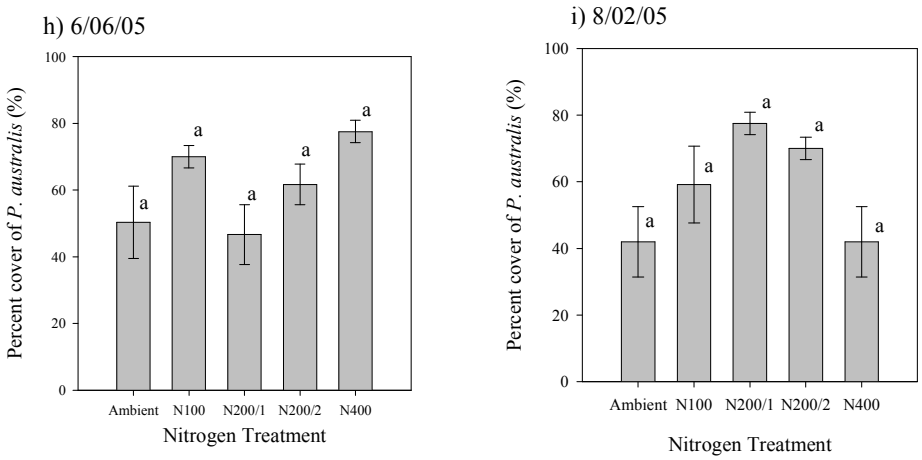



**Figure 3.2.4. Mean *P. australis* percent cover and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. australis* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on A. calamus*

Seasonal and site effects influenced *A. calamus* cover. A clear site effect existed, as *A. calamus* was only found in trace amounts at the *Phragmites*-absent site, but up to 25% cover at the *Phragmites*-dominant site (Figure 3.2.5). Treatment and time analysis at the *Phragmites*-dominant site demonstrated that time did not interact with the treatment effect, but significantly affected *A. calamus* percent cover (Table 3.2.2). The direct seasonal effects on *A. calamus* cover illustrated *A. calamus* peaked on 6/16/04, then decreased in cover through 9/21/04 (Figure 3.2.5).

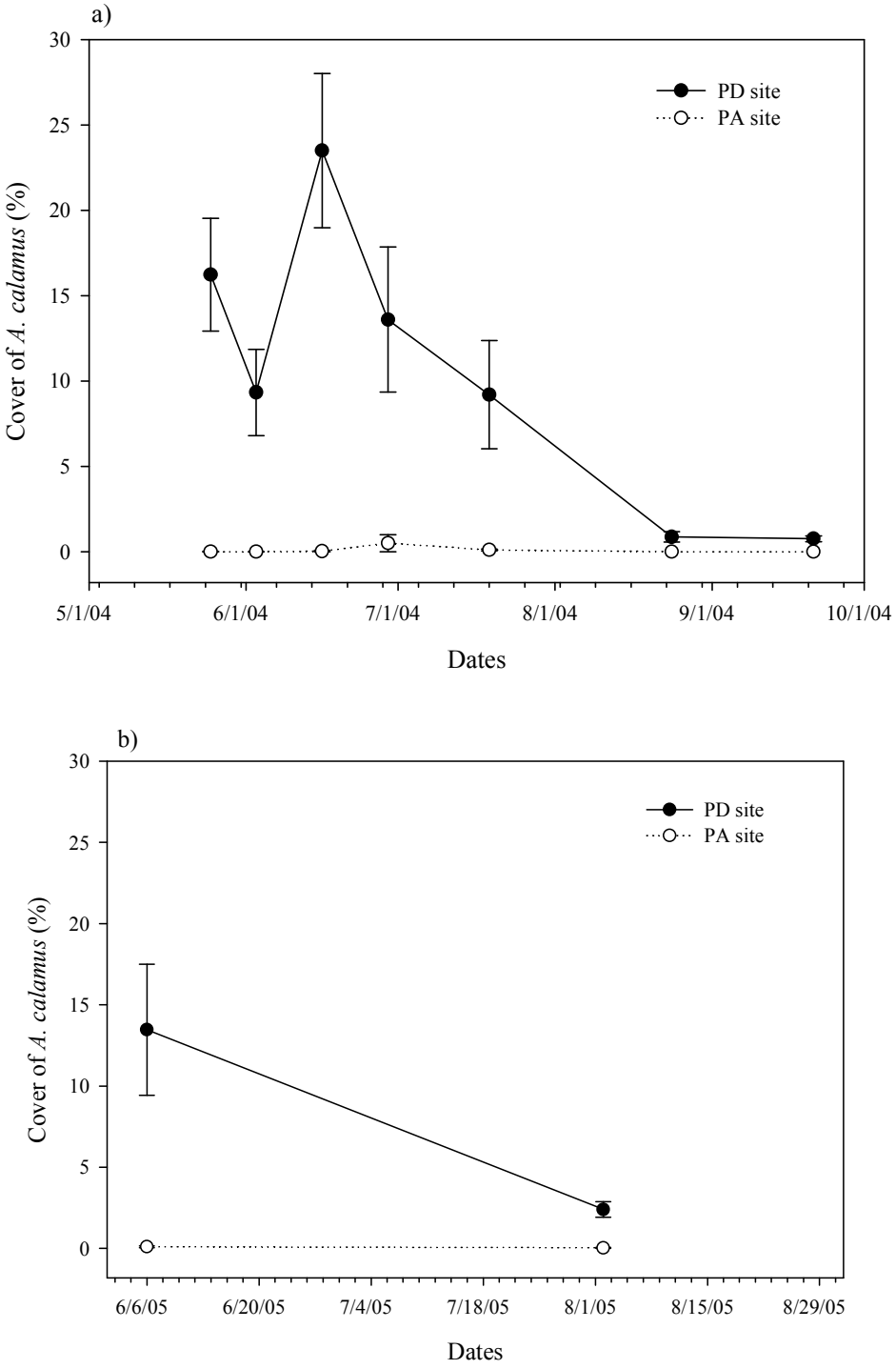
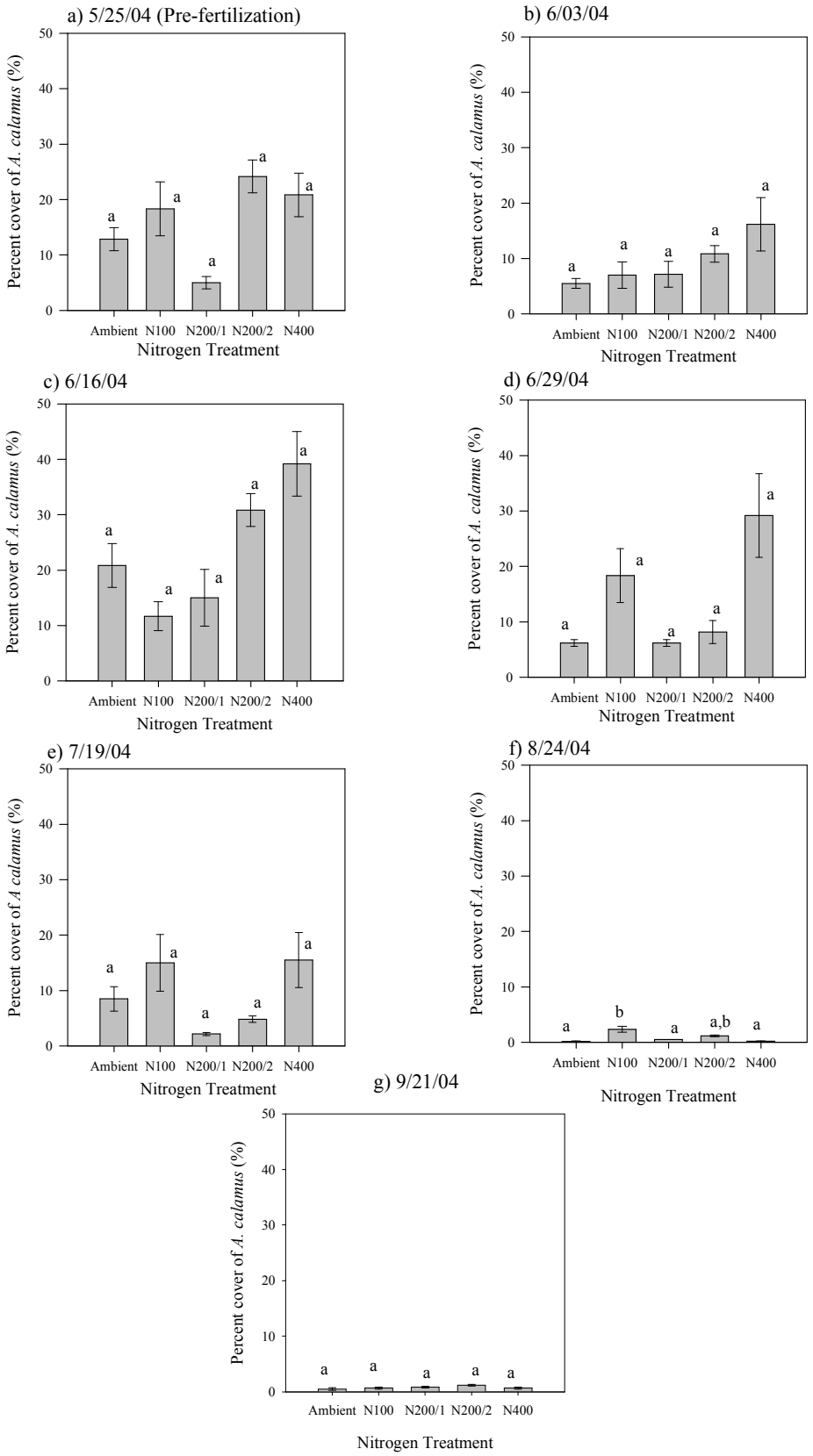



**Figure 3.2.5. Mean percent cover and standard errors of *A. calamus* for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.2. ANOVA model: Trt + Time + (Trt*Time) at the *Phragmites*-dominant site for *A. calamus* percent cover. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 1751.09 | 4 | 437.77 | 0.89 | 0.506 |
| | Time | 6030.10 | 6 | 1005.02 | 12.56 | 0.000*** |
| | Time * Trt | 2356.94 | 24 | 98.21 | 1.23 | 0.257 |
| | Error | 4802.35 | 60 | 80.04 | | |

Nitrogen was not found to affect the cover of *A. calamus* during the majority of the growing season (Figure 3.2.6). However, when *A. calamus* cover was low (<10%) in the late season, there was a slight elevation in its cover for the lowest nitrogen treatment. In general, *A. calamus* percent cover was low for medium nitrogen fertilization and high for large urea applications.


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of A. calamus (%)
Ambient N100 N200/1 N200/2 N400
Nitrogen Treatment

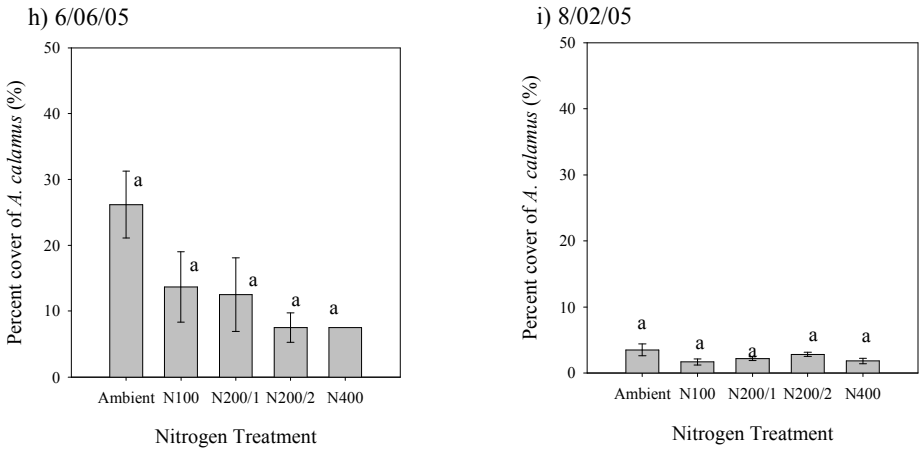



**Figure 3.2.6. Mean *A. calamus* percent cover and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *A. calamus* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on P. arifolium*

Before nitrogen effects were analyzed on *P. arifolium*, site and time effects were evaluated. The *Phragmites*-absent site had a higher percent cover of *P. arifolium* than the *Phragmites*-dominant site for the majority of the season (Figure 3.2.7). Upon analysis, the site*time interaction was significant (Table 3.2.3) and time had a strong effect at each site (Table 3.2.4), which indicated that each date and each site needed to be analyzed separately to detect nitrogen effects (Table 3.2.5). When site and nitrogen effects were analyzed on each sample date, *P. arifolium* cover was significantly different between the two marsh sites at every date except for the pre-fertilization date, 5/25/04.

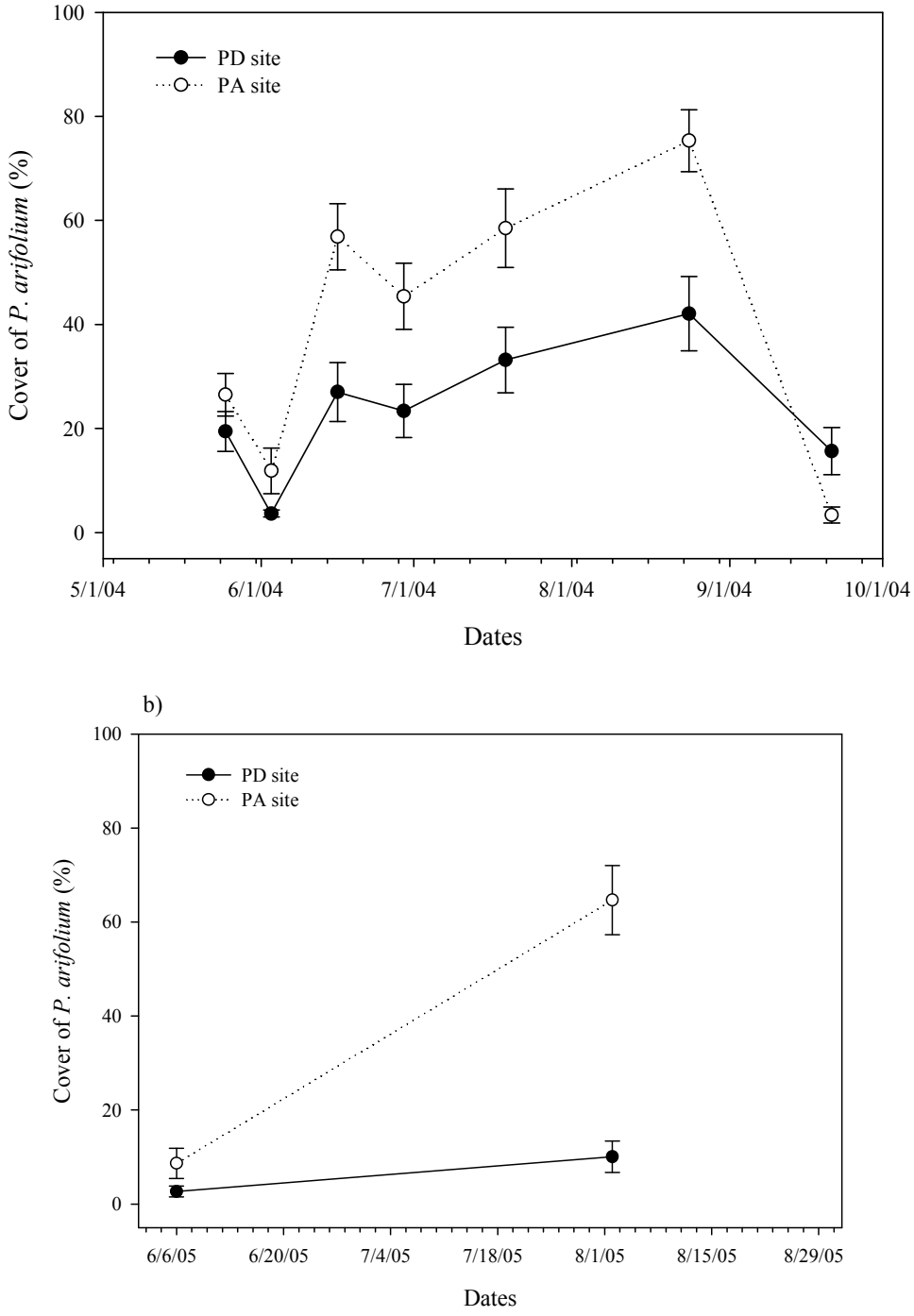



**Figure 3.2.7. Mean percent cover and standard errors of *P. arifolium* for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.3 Repeated measures ANOVA model for 2004 *P. arifolium* populations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 12900.00 | 1 | 12900.00 | 7.80 | 0.012 |
| Trt | 3002.09 | 4 | 750.52 | 0.45 | 0.768 |
| Site * Trt | 5766.44 | 4 | 1441.61 | 0.87 | 0.499 |
| Error | 31404.83 | 19 | 1652.89 | | |
| Time | 63362.18 | 6 | 10560.36 | 39.34 | 0.000 |
| Time * Site | 10248.99 | 6 | 1708.16 | 6.36 | 0.000*** |
| Time * Trt | 4037.68 | 24 | 168.24 | 0.63 | 0.907 |
| Time * Site * Trt | 5654.33 | 24 | 235.60 | 0.88 | 0.631 |
| Error (time) | 30598.87 | 114 | 268.41 | | |

**Table 3.2.4. ANOVA model: Trt + Time + (Trt*Time) at each marsh site for *P. arifolium* percent cover. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 3227.29 | 4 | 806.82 | 0.54 | 0.708 |
| | Time | 12746.78 | 6 | 2124.46 | 7.14 | 0.000*** |
| | Time * Trt | 4127.70 | 24 | 171.99 | 0.58 | 0.929 |
| | Error | 16078.00 | 54 | 297.74 | | |
| PA site | Trt | 6318.66 | 4 | 1579.67 | 0.87 | 0.512 |
| | Time | 63270.26 | 6 | 10545.04 | 43.57 | 0.000*** |
| | Time * Trt | 5463.87 | 24 | 227.66 | 0.94 | 0.551 |
| | Error | 14520.87 | 60 | 242.01 | | |

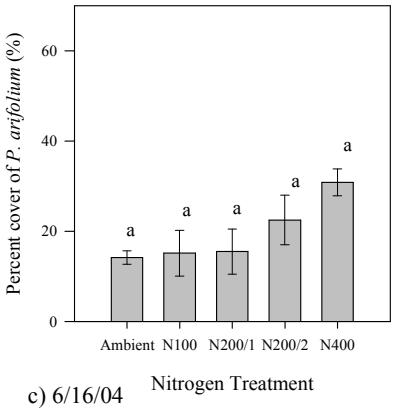
**Table 3.2.5 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for *P. arifolium*. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 336.79 | 1 | 336.79 | 1.17 | 0.294 |
| | Trt | 537.08 | 4 | 134.27 | 0.47 | 0.760 |
| | Site * Trt | 366.11 | 4 | 91.53 | 0.32 | 0.863 |
| | Error | 5483.33 | 19 | 288.60 | | |
| 6/3/2004 | Site | 508.41 | 1 | 508.41 | 3.83 | 0.064* |
| | Trt | 653.33 | 4 | 163.33 | 1.23 | 0.330 |
| | Site * Trt | 860.13 | 4 | 215.03 | 1.62 | 0.208 |
| | Error | 2655.50 | 20 | 132.78 | | |
| 6/16/2004 | Site | 6675.21 | 1 | 6675.21 | 13.41 | 0.002*** |
| | Trt | 2724.17 | 4 | 681.04 | 1.37 | 0.280 |
| | Site * Trt | 2513.33 | 4 | 628.33 | 1.26 | 0.318 |
| | Error | 9958.33 | 20 | 497.92 | | |

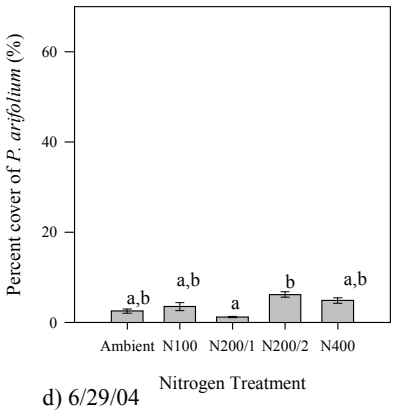
| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 3641.01 | 1 | 3641.01 | 6.88 | 0.016** |
| | Trt | 352.80 | 4 | 88.20 | 0.17 | 0.953 |
| | Site * Trt | 3134.87 | 4 | 783.72 | 1.48 | 0.245 |
| | Error | 10585.17 | 20 | 529.26 | | |
| 7/19/2004 | Site | 4813.33 | 1 | 4813.33 | 5.68 | 0.027** |
| | Trt | 1937.42 | 4 | 484.35 | 0.57 | 0.686 |
| | Site * Trt | 1304.08 | 4 | 326.02 | 0.38 | 0.817 |
| | Error | 16938.83 | 20 | 846.94 | | |
| 8/24/2004 | Site | 8300.03 | 1 | 8300.03 | 11.03 | 0.003*** |
| | Trt | 1196.13 | 4 | 299.03 | 0.40 | 0.808 |
| | Site * Trt | 1925.97 | 4 | 481.49 | 0.64 | 0.640 |
| | Error | 15050.67 | 20 | 752.53 | | |
| 9/21/2004 | Site | 1127.92 | 1 | 1127.92 | 5.83 | 0.025** |
| | Trt | 346.08 | 4 | 86.52 | 0.45 | 0.773 |
| | Site * Trt | 530.69 | 4 | 132.67 | 0.69 | 0.610 |
| | Error | 3869.87 | 20 | 193.49 | | |
| 6/6/2005 | Site | 270.00 | 1 | 270.00 | 3.25 | 0.086* |
| | Trt | 260.00 | 4 | 65.00 | 0.78 | 0.549 |
| | Site * Trt | 545.67 | 4 | 136.42 | 1.64 | 0.202 |
| | Error | 1659.00 | 20 | 82.95 | | |
| 8/2/2005 | Site | 22358.70 | 1 | 22358.70 | 40.43 | 0.000*** |
| | Trt | 1579.72 | 4 | 394.93 | 0.71 | 0.592 |
| | Site * Trt | 1099.88 | 4 | 274.97 | 0.50 | 0.738 |
| | Error | 11061.67 | 20 | 553.08 | | |

Nitrogen was not found to affect the cover of *P. arifolium* during the majority of the growing season at the *Phragmites*-dominant site (Figure 3.2.8). Generally across the season, *P. arifolium* cover was low for medium nitrogen fertilization, especially on 6/03/04. *P. arifolium* cover was at its lowest of the season on 6/03/04 and standard errors were small (Figure 3.2.7a). At all other sample dates in 2004, the percent cover of *P. arifolium* was fairly high and standard errors were large, which lessened the statistical sensitivity.

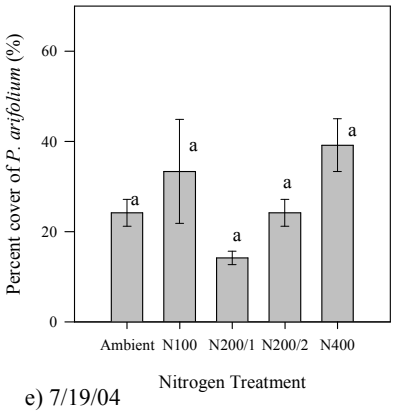
a) 5/25/04 (Pre-fertilization)



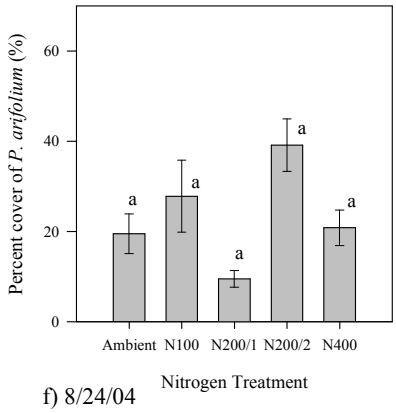

b) 6/03/04



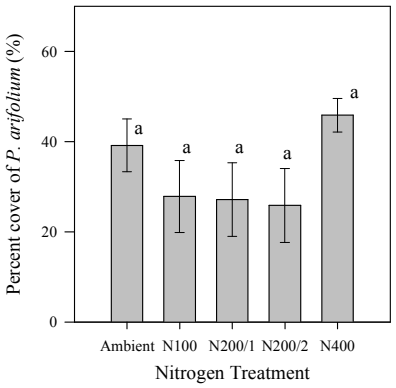

c) 6/16/04



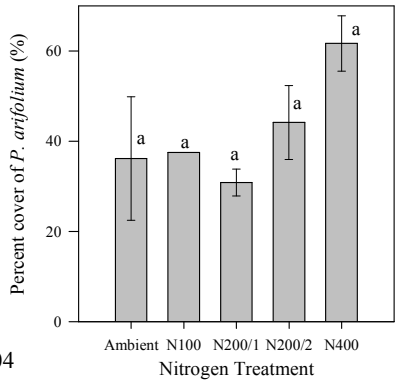

d) 6/29/04



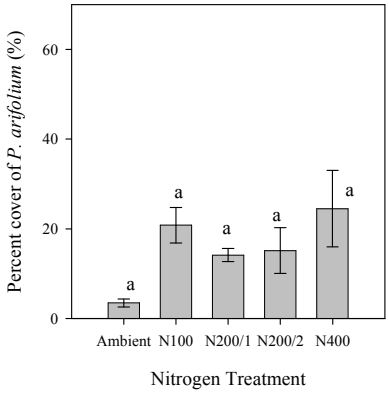

e) 7/19/04




f) 8/24/04




g) 9/21/04



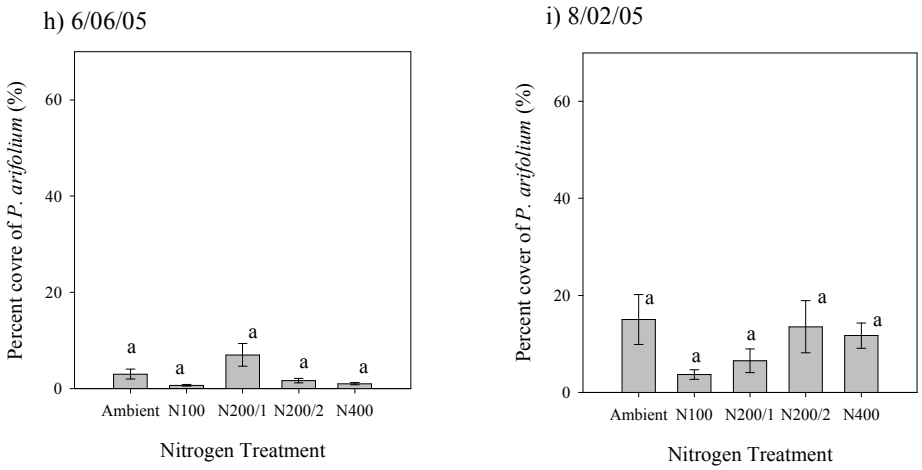
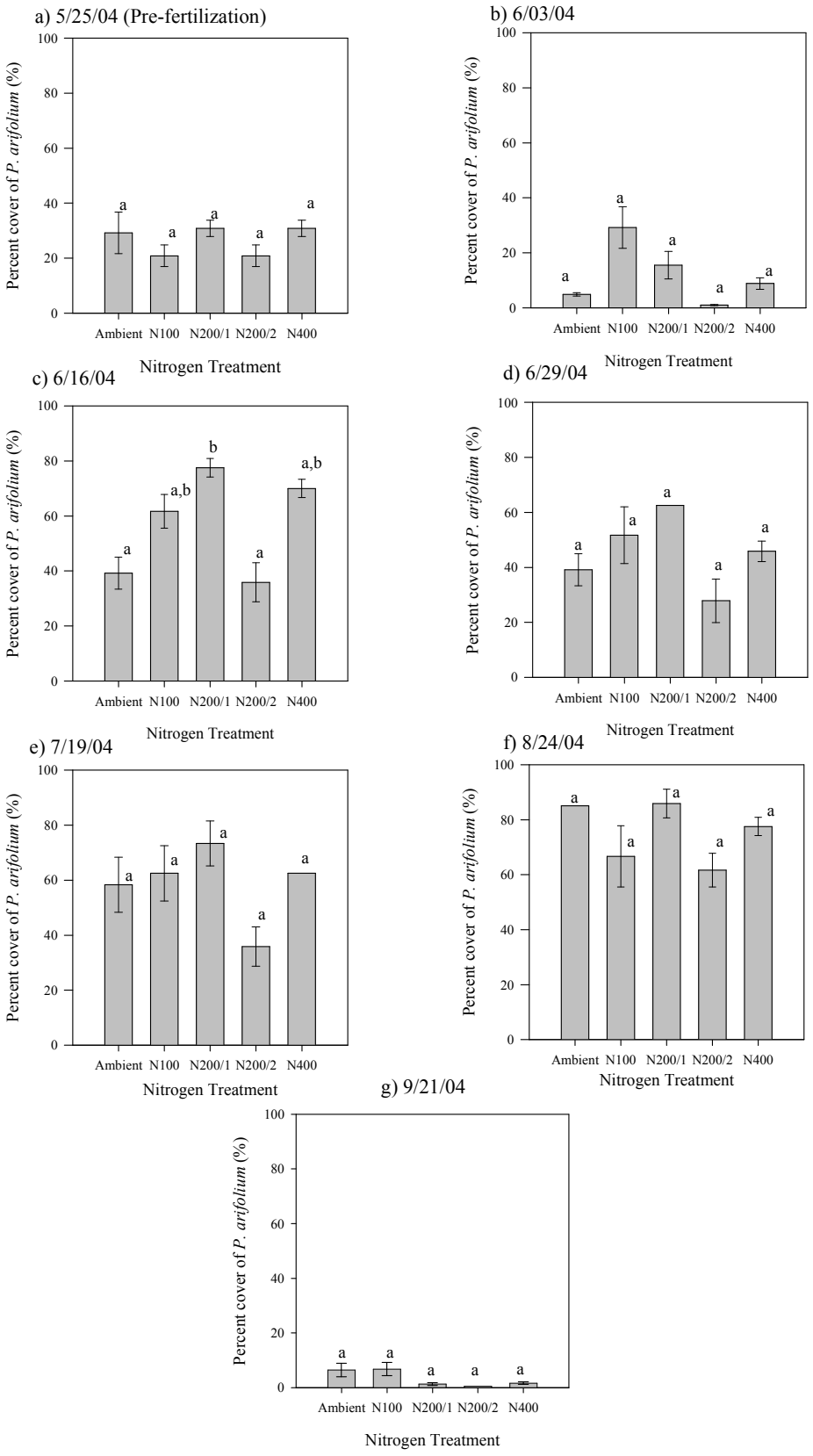



**Figure 3.2.8. Mean *P. arifolium* percent cover and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. arifolium* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

Analysis of the nitrogen effect on *P. arifolium* on each date at the *Phragmites*-absent site was similar to the *Phragmites*-dominant site analysis in that only one date showed a nitrogen effect on *P. arifolium* cover (Figure 3.2.9). Only on 6/16/04 did N200/1D have a greater percent cover of *P. arifolium* (Figure 3.2.9c).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of P. arifolium (%)
Nitrogen Treatment
Ambient
N100
N200/1
N200/2
N400

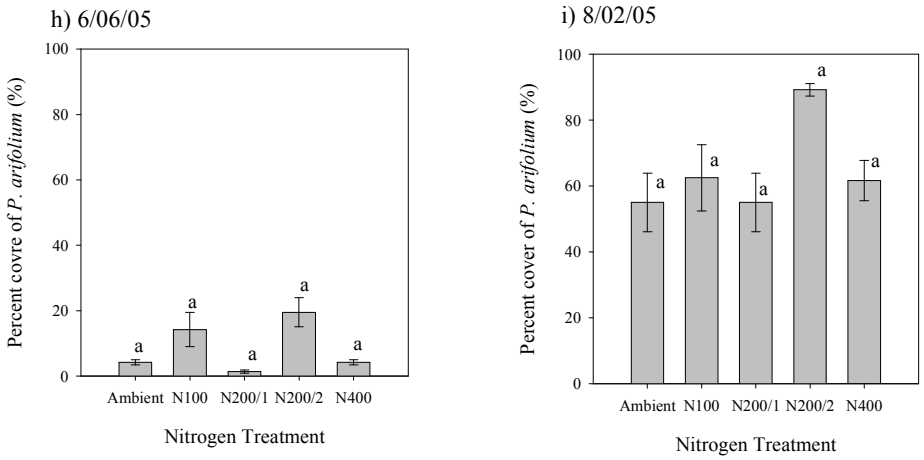



**Figure 3.2.9. Mean *P. arifolium* percent cover and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. arifolium* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on P. virginica*

Nitrogen fertilization effects on *P. virginica* were analyzed by first determining the effect of site and time on *P. virginica* percent cover. Figure 3.2.10 shows that percent cover of *P. virginica* decreased at both sites over the growing season until it was approximately the same at each in August (Figure 3.2.10). Upon analysis, site was found to have an interaction effect on percent cover of *P. virginica* with both the nitrogen and time effects (Table 3.2.6). When individual sites were studied for time and nitrogen effects on *P. virginica*, the time effect on percent cover of *P. virginica* was highly significant for both sites and the nitrogen effect was significant at the *Phragmites*-absent site (Table 3.2.7). Since time had a great effect on percent cover, site and nitrogen effects were studied at each sample date, which determined that site was significant on all sample dates before August (Table 3.2.8).

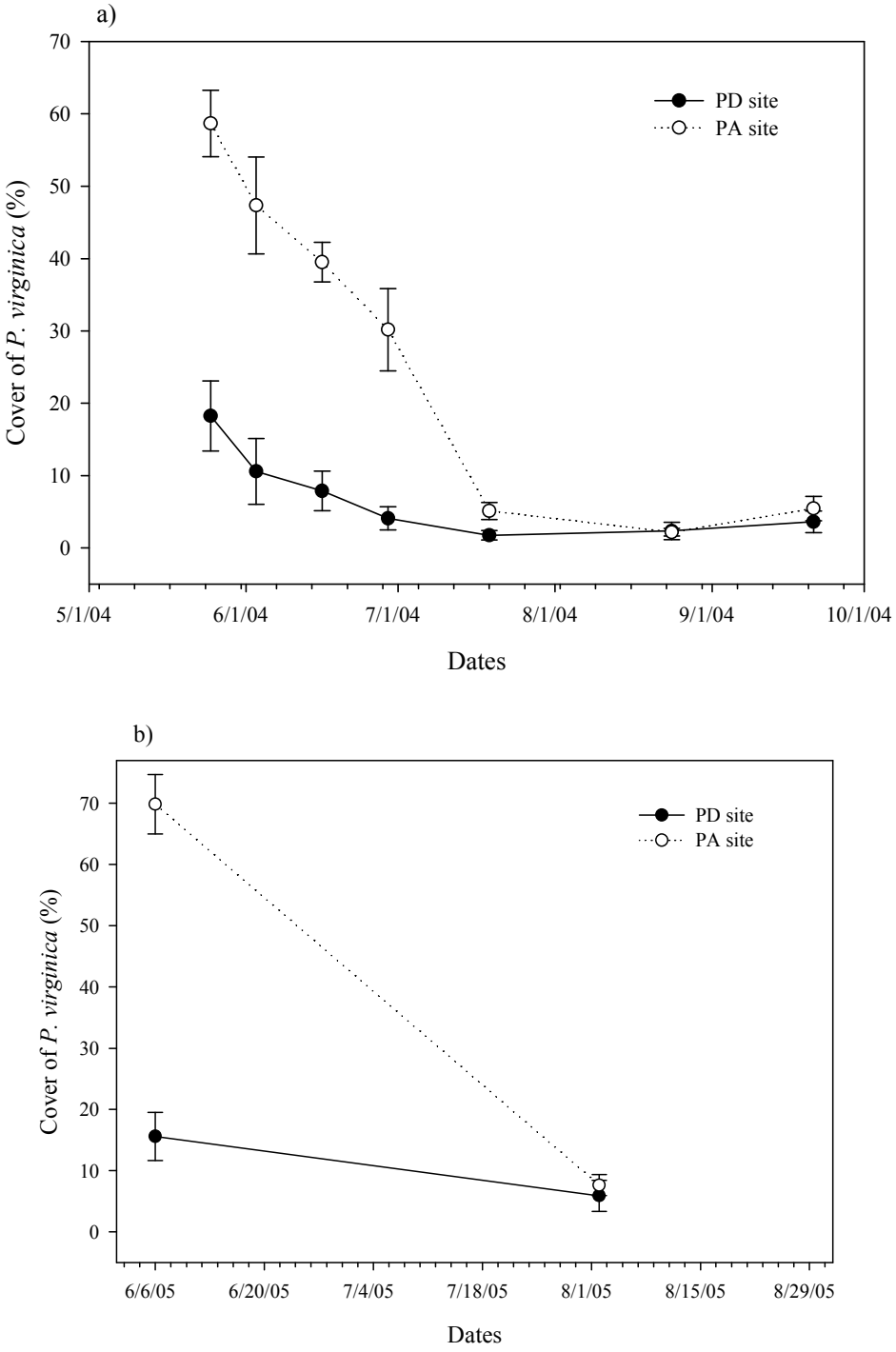



**Figure 3.2.10. Mean percent cover and standard errors of *P. virginica* for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.6 Repeated measures ANOVA model for 2004 *P. virginica* populations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 20986.00 | 1 | 20986.00 | 63.79 | 0.000 |
| Trt | 2024.79 | 4 | 506.20 | 1.54 | 0.229 |
| Site * Trt | 3257.26 | 4 | 814.31 | 2.48 | 0.077* |
| Error | 6580.04 | 20 | 329.00 | | |
| Time | 36156.45 | 6 | 6026.07 | 45.27 | 0.000 |
| Time * Site | 14134.06 | 6 | 2355.68 | 17.70 | 0.000*** |
| Time * Trt | 3816.17 | 24 | 159.01 | 1.19 | 0.261 |
| Time * Site * Trt | 3780.91 | 24 | 157.54 | 1.18 | 0.271 |
| Error (time) | 15974.92 | 120 | 133.12 | | |

**Table 3.2.7. ANOVA model: Trt + Time + (Trt*Time) at each marsh site for *P. virginica* percent cover. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 1342.06 | 4 | 335.51 | 0.89 | 0.507 |
| | Time | 3137.11 | 6 | 522.85 | 5.84 | 0.000*** |
| | Time * Trt | 1757.47 | 24 | 73.23 | 0.82 | 0.701 |
| | Error | 5373.49 | 60 | 89.56 | | |
| PA site | Trt | 3939.99 | 4 | 985.00 | 3.53 | 0.048** |
| | Time | 47153.40 | 6 | 7858.90 | 44.48 | 0.000*** |
| | Time * Trt | 5839.62 | 24 | 243.32 | 1.38 | 0.159 |
| | Error | 10601.43 | 60 | 176.69 | | |

**Table 3.2.8 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for *P. virginica.* *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 12261.41 | 1 | 12261.41 | 41.68 | 0.000*** |
| | Trt | 1307.47 | 4 | 326.87 | 1.11 | 0.379 |
| | Site * Trt | 2158.13 | 4 | 539.53 | 1.83 | 0.162 |
| | Error | 5883.17 | 20 | 294.16 | | |
| 6/3/2004 | Site | 10138.41 | 1 | 10138.41 | 23.45 | 0.000*** |
| | Trt | 2532.30 | 4 | 633.07 | 1.46 | 0.250 |
| | Site * Trt | 2589.47 | 4 | 647.37 | 1.50 | 0.241 |
| | Error | 8647.00 | 20 | 432.35 | | |
| 6/16/2004 | Site | 7505.01 | 1 | 7505.01 | 61.24 | 0.000*** |
| | Trt | 181.95 | 4 | 45.49 | 0.37 | 0.826 |
| | Site * Trt | 537.28 | 4 | 134.32 | 1.10 | 0.386 |
| | Error | 2451.00 | 20 | 122.55 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 5105.16 | 1 | 5105.16 | 23.34 | 0.000*** |
| | Trt | 1637.74 | 4 | 409.44 | 1.87 | 0.155 |
| | Site * Trt | 1317.87 | 4 | 329.47 | 1.51 | 0.238 |
| | Error | 4374.44 | 20 | 218.72 | | |
| 7/19/2004 | Site | 84.67 | 1 | 84.67 | 6.92 | 0.016 |
| | Trt | 21.08 | 4 | 5.27 | 0.43 | 0.785 |
| | Site * Trt | 116.73 | 4 | 29.18 | 2.38 | 0.086* |
| | Error | 244.89 | 20 | 12.24 | | |
| 8/24/2004 | Site | 0.20 | 1 | 0.20 | 0.01 | 0.905 |
| | Trt | 43.00 | 4 | 10.75 | 0.79 | 0.545 |
| | Site * Trt | 48.62 | 4 | 12.15 | 0.89 | 0.486 |
| | Error | 271.84 | 20 | 13.59 | | |
| 9/21/2004 | Site | 25.21 | 1 | 25.21 | 0.74 | 0.400 |
| | Trt | 117.43 | 4 | 29.36 | 0.86 | 0.505 |
| | Site * Trt | 270.07 | 4 | 67.52 | 1.98 | 0.137 |
| | Error | 682.64 | 20 | 34.13 | | |
| 6/6/2005 | Site | 22059.41 | 1 | 22059.41 | 81.21 | 0.000*** |
| | Trt | 461.05 | 4 | 115.26 | 0.42 | 0.789 |
| | Site * Trt | 2297.22 | 4 | 574.30 | 2.11 | 0.117 |
| | Error | 5432.67 | 20 | 271.63 | | |
| 8/2/2005 | Site | 22.45 | 1 | 22.45 | 0.31 | 0.586 |
| | Trt | 134.67 | 4 | 33.67 | 0.46 | 0.765 |
| | Site * Trt | 375.41 | 4 | 93.85 | 1.28 | 0.311 |
| | Error | 1465.67 | 20 | 73.28 | | |

Nitrogen effects on *P. virginica* percent cover for individual dates and sites were evaluated. Figure 3.2.11 shows no nitrogen effect on *P. virginica* percent cover for 2004 sample dates at the *Phragmites*-dominant site. At the *Phragmites*-absent site, N400 was significantly lower on 6/03/04 (Figure 3.2.12). By 7/19/04, *P. virginica* had been out-competed at the *Phragmites*-absent site by other species, primarily *P. arifolium* (Figure 3.2.7a). No nitrogen effects on percent *P. virginica* cover were detected in the 2005 season for either site (Figure 3.2.13).

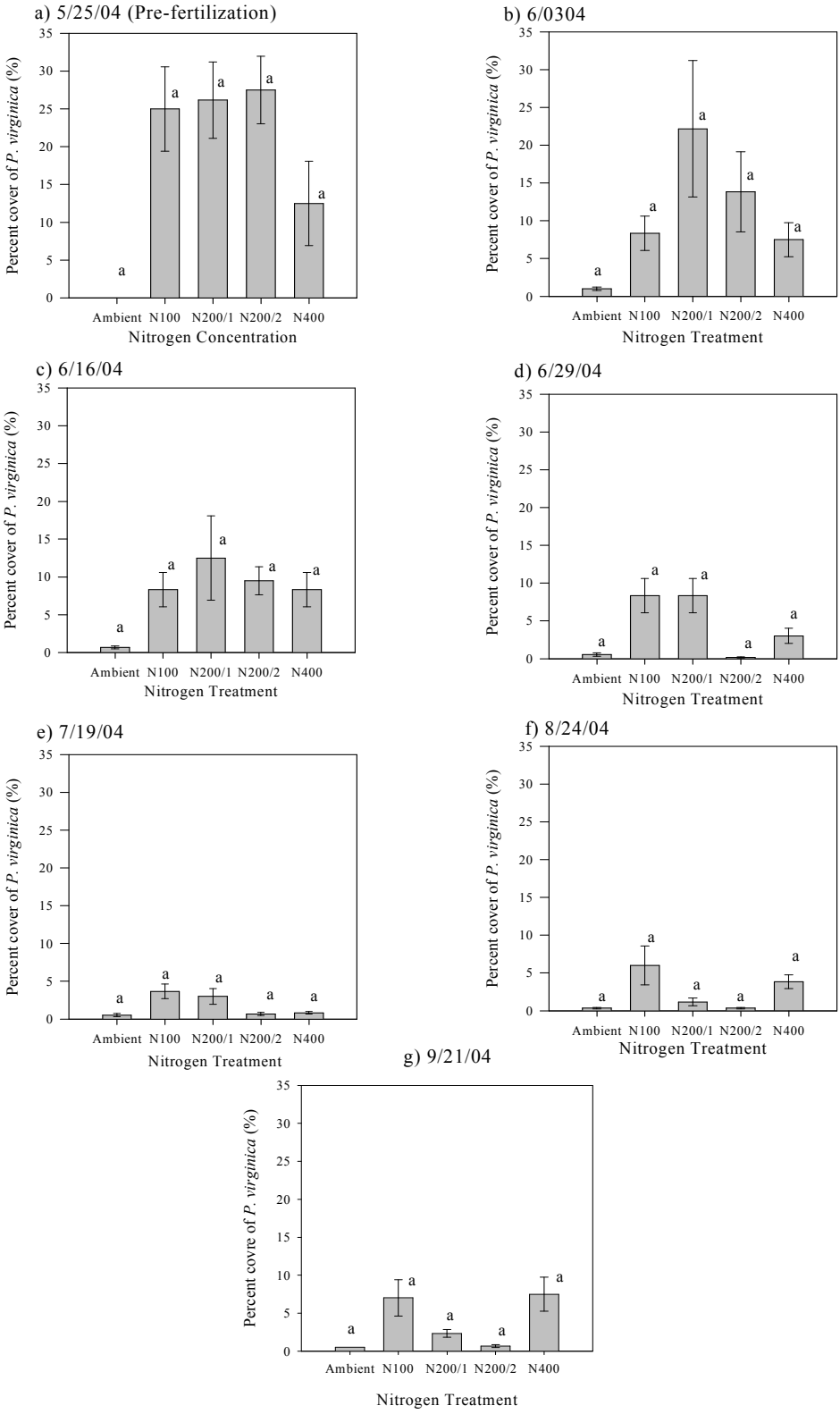



**Figure 3.2.11. Mean *P. virginica* percent cover and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. virginica* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

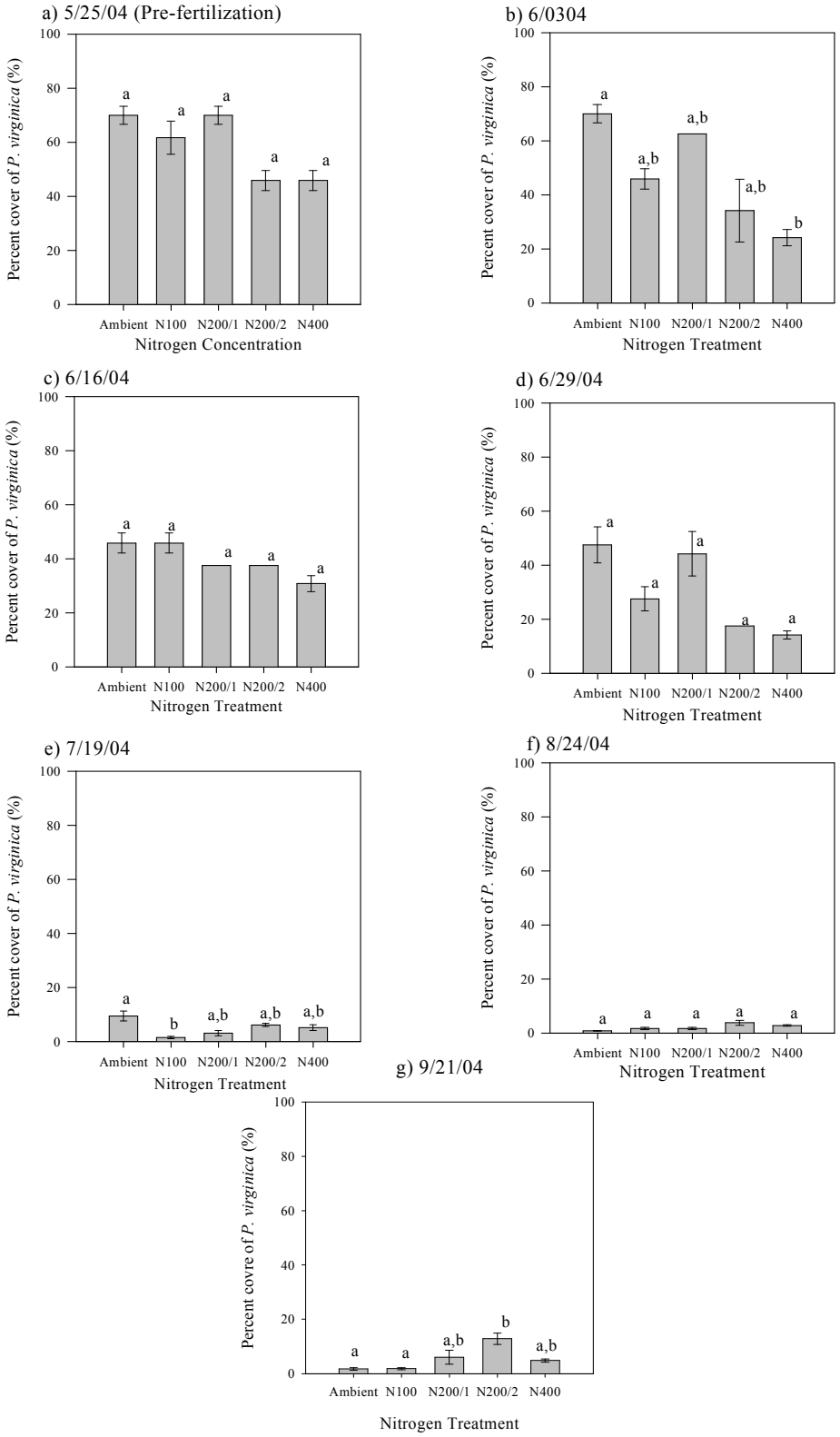



**Figure 3.2.12. Mean *P. virginica* percent cover and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. virginica* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

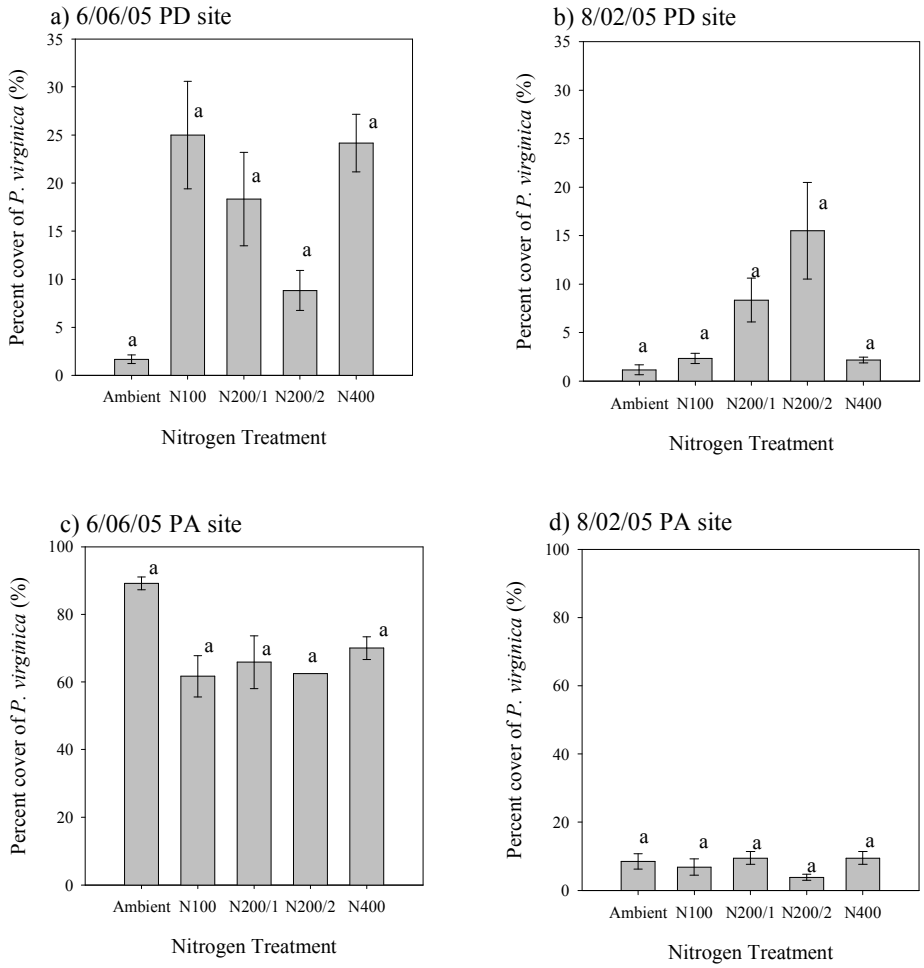
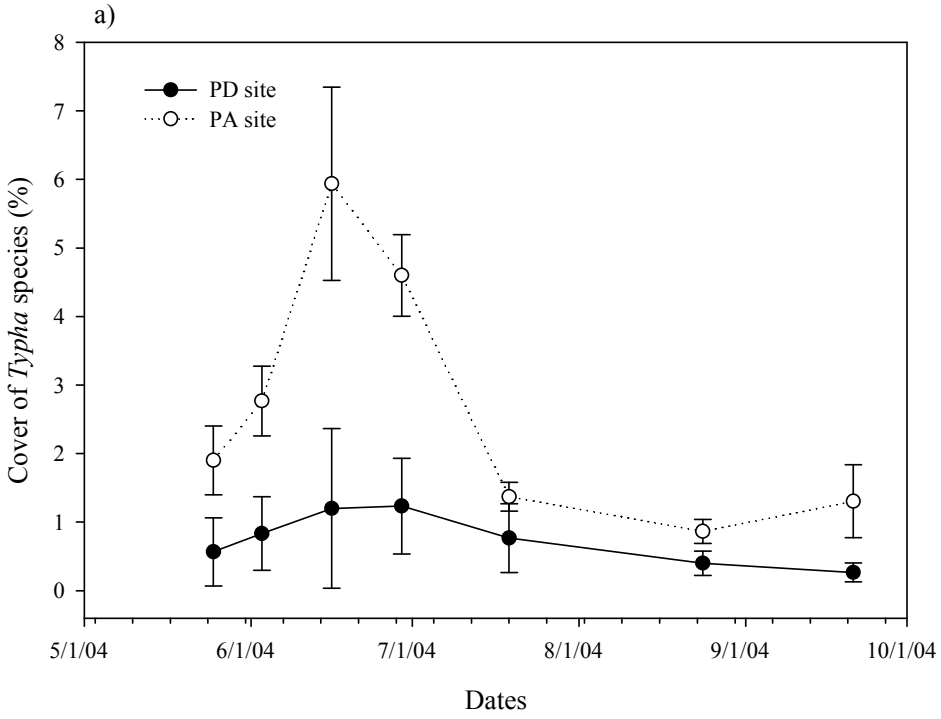



**Figure 3.2.13. Mean *P. virginica* percent cover and standard errors according to nitrogen treatment over the 2005 growing seasons at both the *Phragmites*-dominant and *Phragmites*-absent site. (a) 6/06/05 *Phragmites*-dominant site, (b) 8/02/05 *Phragmites*-dominant site, (c) 6/06/05 *Phragmites*-absent site, (d) 8/02/05 *Phragmites*-absent site. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *P. virginica* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on Typha species*

The effect of nitrogen fertilization on *Typha* species percent cover was analyzed after site and time effects were determined. The two marsh sites appeared to differ from each other, especially in June when the *Phragmites*-absent site had a greater *Typha* species percent cover than the *Phragmites*-dominant site (Figure 3.2.14). In the analysis, site had an interaction effect with time (Table 3.2.9), so nitrogen effects at

individual sites (Table 3.2.10) and on individual dates (Table 3.2.11) were then analyzed. As expected, no time effect on *Typha* species was detected at the *Phragmites*-dominant site, unlike the *Phragmites*-absent site where a large time effect was distinguished (Table 3.2.10). When site and nitrogen effects were studied on each sample date, it was discovered that *Typha* species had a higher percent cover at the *Phragmites*-absent site than at the *Phragmites*-dominant site in June (Table 3.2.11). Also, in late June (6/29/04), a nitrogen effect on *Typha* species percent cover was detected (Table 3.2.11).



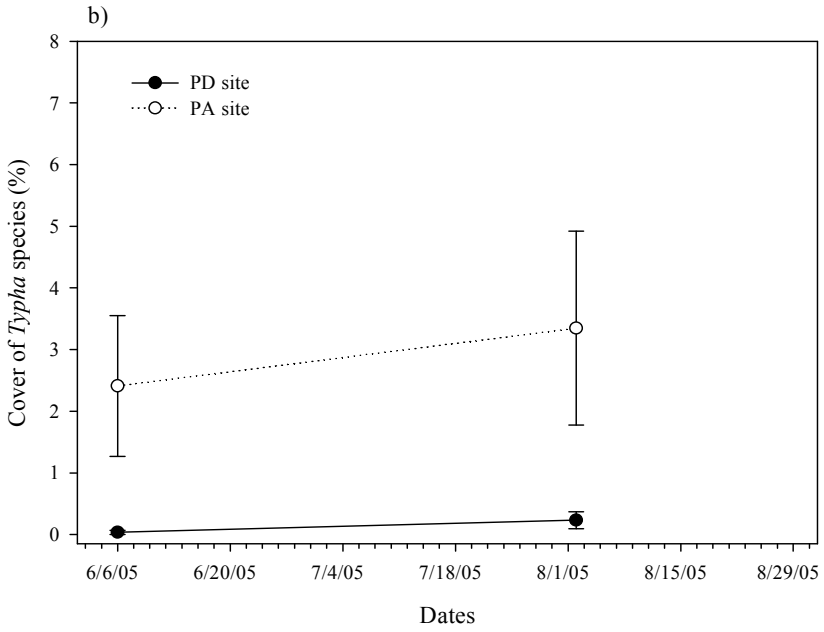



**Figure 3.2.14. Mean percent cover and standard errors of *Typha* species for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.9 Repeated measures ANOVA model for 2004 *Typha* species populations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 178.20 | 1 | 178.20 | 10.77 | 0.004 |
| Trt | 92.09 | 4 | 23.02 | 1.39 | 0.275 |
| Site * Trt | 72.81 | 4 | 18.20 | 1.10 | 0.385 |
| Error | 314.46 | 19 | 16.55 | | |
| Time | 202.82 | 6 | 33.80 | 7.29 | 0.000 |
| Time * Site | 96.51 | 6 | 16.08 | 3.47 | 0.003*** |
| Time * Trt | 110.52 | 24 | 4.61 | 0.99 | 0.481 |
| Time * Site * Trt | 106.20 | 24 | 4.42 | 0.95 | 0.531 |
| Error (time) | 528.65 | 114 | 4.64 | | |

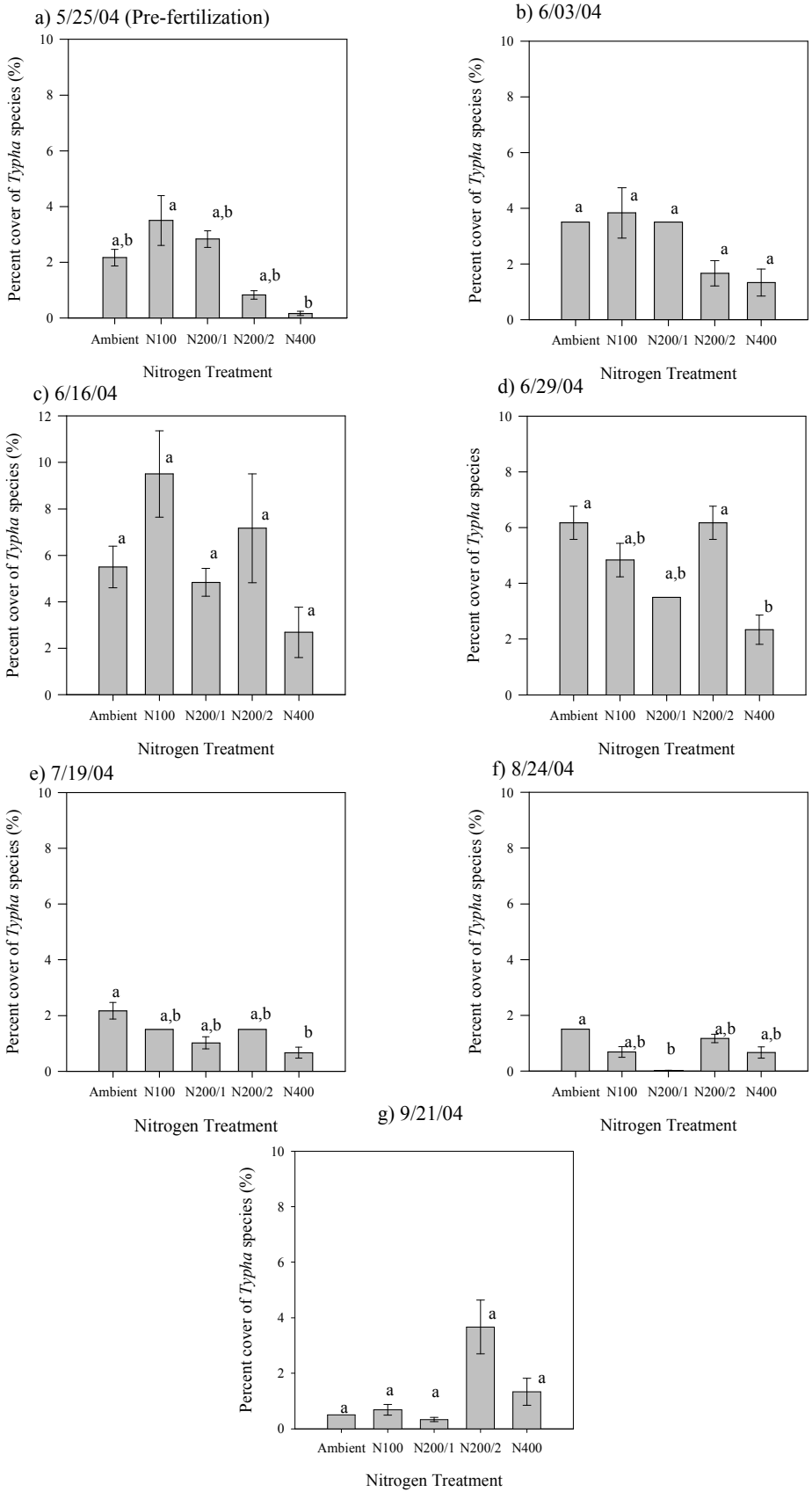
**Table 3.2.10. ANOVA model: Trt + Time + (Trt*Time) at each marsh site for *Typha* species percent cover. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 100.40 | 4 | 25.10 | 1.47 | 0.282 |
| | Time | 12.50 | 6 | 2.08 | 0.64 | 0.695 |
| | Time * Trt | 97.00 | 24 | 4.04 | 1.25 | 0.240 |
| | Error | 194.14 | 60 | 3.24 | | |
| PA site | Trt | 65.77 | 4 | 16.44 | 1.03 | 0.443 |
| | Time | 274.36 | 6 | 45.73 | 7.38 | 0.000*** |
| | Time * Trt | 117.77 | 24 | 4.91 | 0.79 | 0.730 |
| | Error | 334.51 | 54 | 6.19 | | |

**Table 3.2.11 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for *Typha* species. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 13.33 | 1 | 13.33 | 4.07 | 0.057 |
| | Trt | 10.37 | 4 | 2.59 | 0.79 | 0.544 |
| | Site * Trt | 29.17 | 4 | 7.29 | 2.23 | 0.103 |
| | Error | 65.50 | 20 | 3.28 | | |
| 6/3/2004 | Site | 28.03 | 1 | 28.03 | 8.29 | 0.009 |
| | Trt | 9.30 | 4 | 2.33 | 0.69 | 0.609 |
| | Site * Trt | 37.80 | 4 | 9.45 | 2.79 | 0.054* |
| | Error | 67.67 | 20 | 3.38 | | |
| 6/16/2004 | Site | 168.27 | 1 | 168.27 | 6.20 | 0.022** |
| | Trt | 100.89 | 4 | 25.22 | 0.93 | 0.467 |
| | Site * Trt | 58.28 | 4 | 14.57 | 0.54 | 0.710 |
| | Error | 542.57 | 20 | 27.13 | | |
| 6/29/2004 | Site | 85.01 | 1 | 85.01 | 19.81 | 0.000*** |
| | Trt | 60.67 | 4 | 15.17 | 3.53 | 0.025** |
| | Site * Trt | 29.53 | 4 | 7.38 | 1.72 | 0.185 |
| | Error | 85.83 | 20 | 4.29 | | |
| 7/19/2004 | Site | 2.73 | 1 | 2.73 | 1.20 | 0.287 |
| | Trt | 3.56 | 4 | 0.89 | 0.39 | 0.813 |
| | Site * Trt | 12.40 | 4 | 3.10 | 1.36 | 0.283 |
| | Error | 45.57 | 20 | 2.28 | | |
| 8/24/2004 | Site | 1.19 | 1 | 1.19 | 2.53 | 0.128 |
| | Trt | 2.92 | 4 | 0.73 | 1.55 | 0.227 |
| | Site * Trt | 0.96 | 4 | 0.24 | 0.51 | 0.728 |
| | Error | 8.94 | 19 | 0.47 | | |
| 9/21/2004 | Site | 8.06 | 1 | 8.06 | 4.04 | 0.058 |
| | Trt | 11.01 | 4 | 2.75 | 1.38 | 0.277 |
| | Site * Trt | 12.27 | 4 | 3.07 | 1.54 | 0.230 |
| | Error | 39.94 | 20 | 2.00 | | |
| 6/6/2005 | Site | 42.25 | 1 | 42.25 | 4.58 | 0.045** |
| | Trt | 44.16 | 4 | 11.04 | 1.20 | 0.343 |
| | Site * Trt | 45.07 | 4 | 11.27 | 1.22 | 0.333 |
| | Error | 184.39 | 20 | 9.22 | | |
| 8/2/2005 | Site | 72.70 | 1 | 72.70 | 5.80 | 0.026 |
| | Trt | 132.55 | 4 | 33.14 | 2.64 | 0.064 |
| | Site * Trt | 138.74 | 4 | 34.68 | 2.77 | 0.056* |
| | Error | 250.66 | 20 | 12.53 | | |

To analyze the nitrogen effect on *Typha* species percent cover without site and time effects, nitrogen treatments were evaluated at the *Phragmites*-absent site for each sample date (Figure 3.2.15). Overall, *Typha* species percent cover was visually lower for N400, and in late June (6/29/04), *Typha* species percent cover for N400 was significantly lower than other treatments (Figure 3.2.15d). Interestingly, one of the nitrogen additions (N200/2D) increased mean cover of *Typha* species by September (Figure 3.2.15g), which was present during the early part of the next season and remained until the last measurement in August (Figure 3.2.15i)


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of Typha species (%)
Ambient N100 N200/1 N200/2 N400
Nitrogen Treatment
a
a,b
b

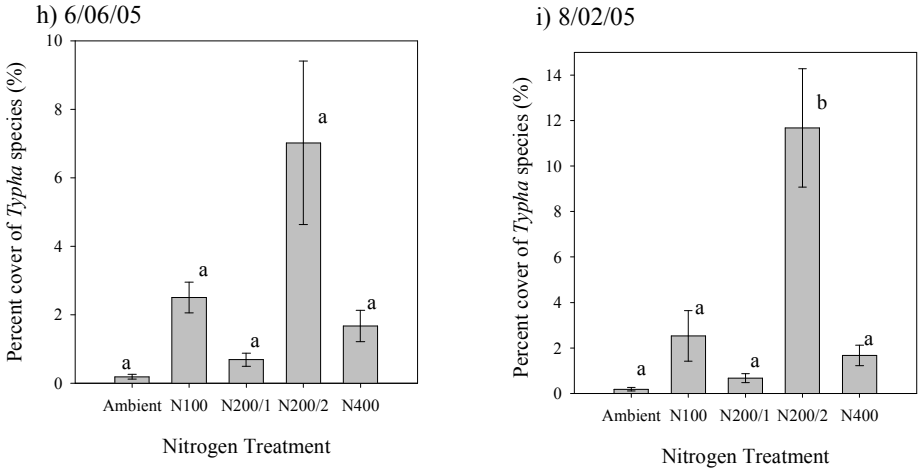



**Figure 3.2.15. Mean *Typha* species percent cover and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *Typha* species was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on I. capensis*

To determine if nitrogen fertilization affected *I. capensis* percent cover, site and time effects were first evaluated. Although the marsh sites appeared to have similar percent covers of *I. capensis* over the growing season (Figure 3.2.16), the site effect did interact with time for *I. capensis* percent cover (Table 3.2.12). Time effect on *I. capensis* percent cover was also noticed at both marsh sites when analyzed individually (Table 3.2.13). A nitrogen effect was also detected at the *Phragmites*-dominant site (Table 3.2.13). When time effects were eliminated by analyzing site and nitrogen effects on each sample date, marsh sites were not found to be different from each other in *I. capensis* percent cover (Table 3.2.14). Interestingly, a strong treatment effect was discovered for *I. capensis* on 8/02/05 (Table 3.2.14).

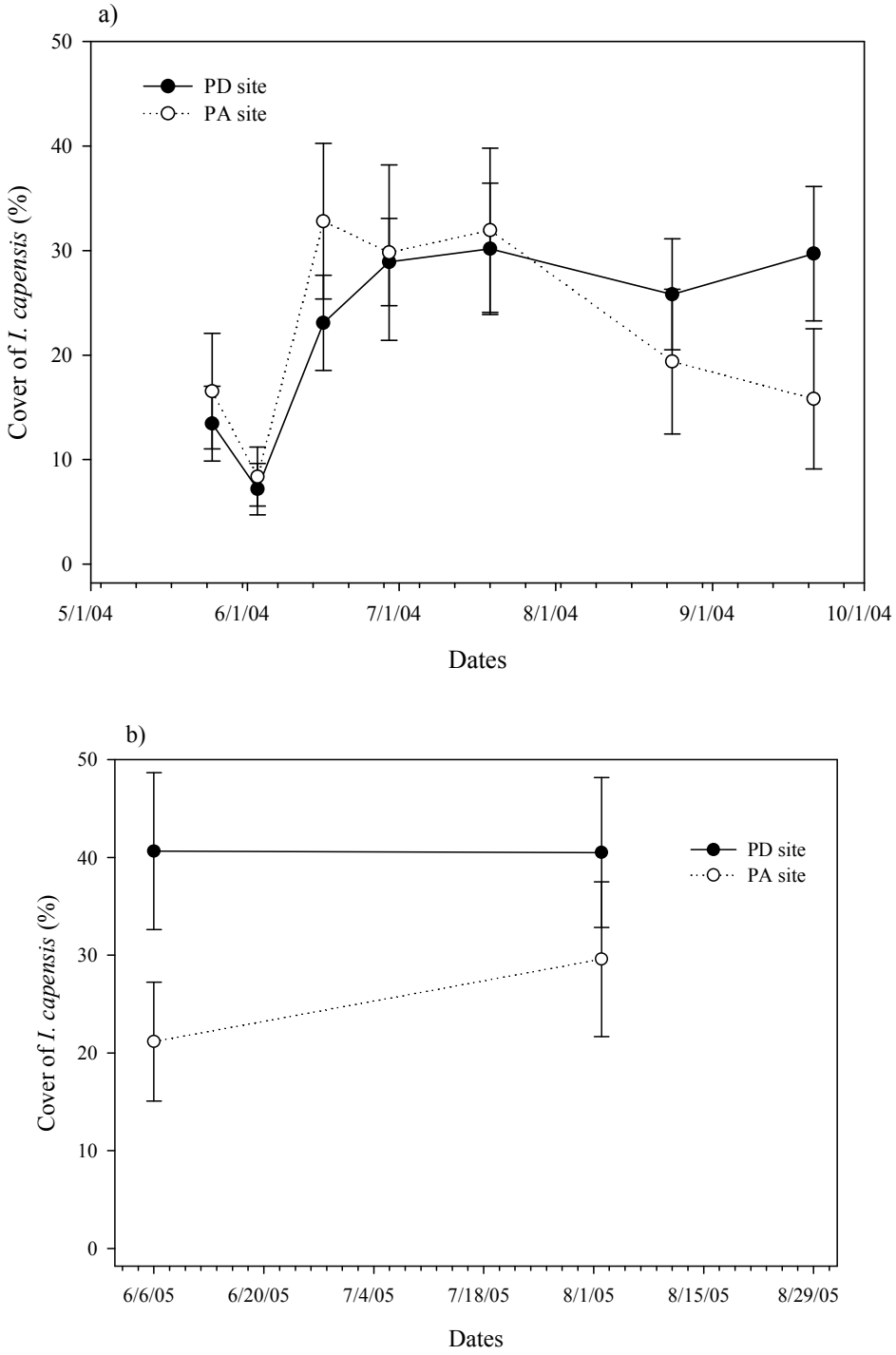



**Figure 3.2.16. Mean percent cover and standard errors of *I. capensis* for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.12 Repeated measures ANOVA model for 2004 *I. capensis* populations. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 14.07 | 1 | 14.07 | 0.01 | 0.943 |
| Trt | 11672.14 | 4 | 2918.03 | 1.10 | 0.384 |
| Site * Trt | 3876.63 | 4 | 969.16 | 0.37 | 0.831 |
| Error | 53101.11 | 20 | 2655.06 | | |
| Time | 12688.49 | 6 | 2114.75 | 11.40 | 0.000 |
| Time * Site | 2566.69 | 6 | 427.78 | 2.31 | 0.038** |
| Time * Trt | 6287.41 | 24 | 261.98 | 1.41 | 0.115 |
| Time * Site * Trt | 4678.89 | 24 | 194.95 | 1.05 | 0.410 |
| Error (time) | 22257.13 | 120 | 185.48 | | |

**Table 3.2.13. ANOVA model: Trt + Time + (Trt*Time) at each marsh site for *I. capensis* percent cover. *** <0.01, ** < 0.05, * < 0.10**

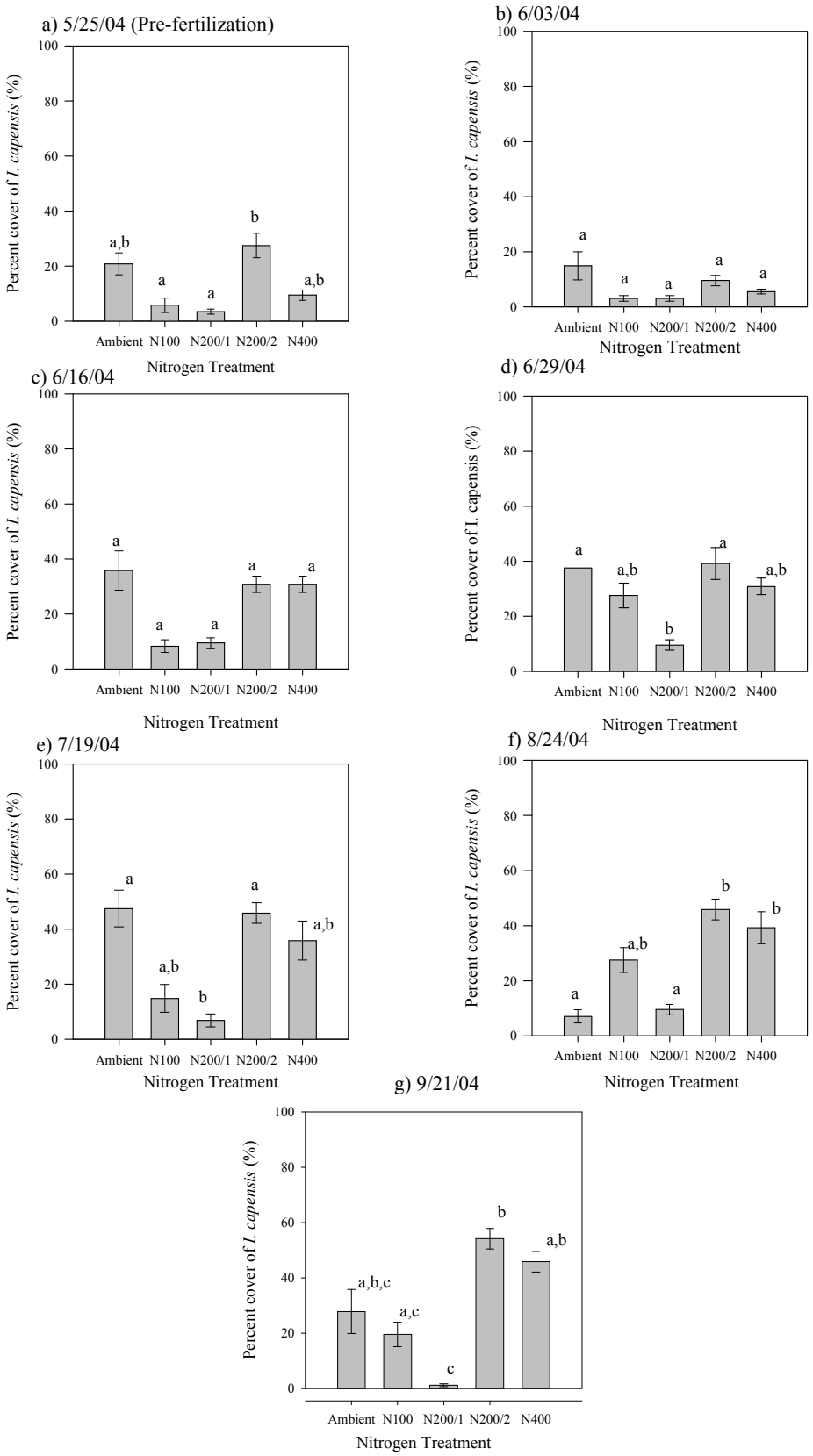
| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 11801.94 | 4 | 2950.48 | 6.60 | 0.007*** |
| | Time | 7198.87 | 6 | 1199.81 | 5.98 | 0.000*** |
| | Time * Trt | 6535.41 | 24 | 272.31 | 1.36 | 0.170 |
| | Error | 12047.67 | 60 | 200.79 | | |
| PA site | Trt | 3746.83 | 4 | 936.71 | 0.19 | 0.937 |
| | Time | 8056.31 | 6 | 1342.72 | 7.89 | 0.000*** |
| | Time * Trt | 4430.89 | 24 | 184.62 | 1.08 | 0.387 |
| | Error | 10209.46 | 60 | 170.16 | | |

**Table 3.2.14 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for *I. capensis.* *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 72.23 | 1 | 72.23 | 0.19 | 0.666 |
| | Trt | 797.54 | 4 | 199.39 | 0.53 | 0.714 |
| | Site * Trt | 793.14 | 4 | 198.28 | 0.53 | 0.716 |
| | Error | 7504.84 | 20 | 375.24 | | |
| 6/3/2004 | Site | 10.74 | 1 | 10.74 | 0.09 | 0.769 |
| | Trt | 203.64 | 4 | 50.91 | 0.42 | 0.793 |
| | Site * Trt | 297.51 | 4 | 74.38 | 0.61 | 0.659 |
| | Error | 2431.70 | 20 | 121.59 | | |
| 6/16/2004 | Site | 710.53 | 1 | 710.53 | 1.21 | 0.284 |
| | Trt | 2537.78 | 4 | 634.45 | 1.08 | 0.391 |
| | Site * Trt | 1758.72 | 4 | 439.68 | 0.75 | 0.569 |
| | Error | 11715.33 | 20 | 585.77 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 6.07 | 1 | 6.07 | 0.01 | 0.932 |
| | Trt | 1362.45 | 4 | 340.61 | 0.42 | 0.795 |
| | Site * Trt | 696.72 | 4 | 174.18 | 0.21 | 0.928 |
| | Error | 16380.83 | 20 | 819.04 | | |
| 7/19/2004 | Site | 23.41 | 1 | 23.41 | 0.03 | 0.860 |
| | Trt | 4773.05 | 4 | 1193.26 | 1.62 | 0.209 |
| | Site * Trt | 1743.38 | 4 | 435.85 | 0.59 | 0.673 |
| | Error | 14761.83 | 20 | 738.09 | | |
| 8/24/2004 | Site | 310.09 | 1 | 310.09 | 0.57 | 0.459 |
| | Trt | 3908.95 | 4 | 977.24 | 1.80 | 0.169 |
| | Site * Trt | 1237.58 | 4 | 309.40 | 0.57 | 0.688 |
| | Error | 10860.17 | 20 | 543.01 | | |
| 9/21/2004 | Site | 1447.69 | 1 | 1447.69 | 2.47 | 0.131 |
| | Trt | 4376.13 | 4 | 1094.03 | 1.87 | 0.155 |
| | Site * Trt | 2028.47 | 4 | 507.12 | 0.87 | 0.501 |
| | Error | 11703.54 | 20 | 585.18 | | |
| 6/6/2005 | Site | 2843.11 | 1 | 2843.11 | 3.98 | 0.060* |
| | Trt | 4055.44 | 4 | 1013.86 | 1.42 | 0.264 |
| | Site * Trt | 2916.48 | 4 | 729.12 | 1.02 | 0.421 |
| | Error | 14298.09 | 20 | 714.90 | | |
| 8/2/2005 | Site | 891.07 | 1 | 891.07 | 1.35 | 0.260 |
| | Trt | 11240.18 | 4 | 2810.05 | 4.24 | 0.012** |
| | Site * Trt | 990.28 | 4 | 247.57 | 0.37 | 0.825 |
| | Error | 13247.64 | 20 | 662.38 | | |

Nitrogen effects on *I. capensis* percent cover were analyzed at each marsh site and sample date so that site and time effects would not influence nitrogen effects. At the *Phragmites*-dominant site, percent cover for N200/1D was lower than other treatments in late-June through September (Figure 3.2.17). *I. capensis* percent cover was visually higher for high fertilization treatments, as well as ambient conditions, while middle treatments yielded a low percent cover. Also, in the 2005 growing season, N400 yielded a higher percent *I. capensis* cover than other treatments (Figure 3.2.17i).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of I. capensis (%)
Percent cover of I. capensis (%)
Ambient N100 N200/1 N200/2 N400
Nitrogen Treatment
a,b
a
a
b
a,b
a
a
a
a
a
a
a
a
a
a
a,b
b
a,b
a
a
a,b
a
a,b
b
b
a,b,c
a,c
c
b
a,b

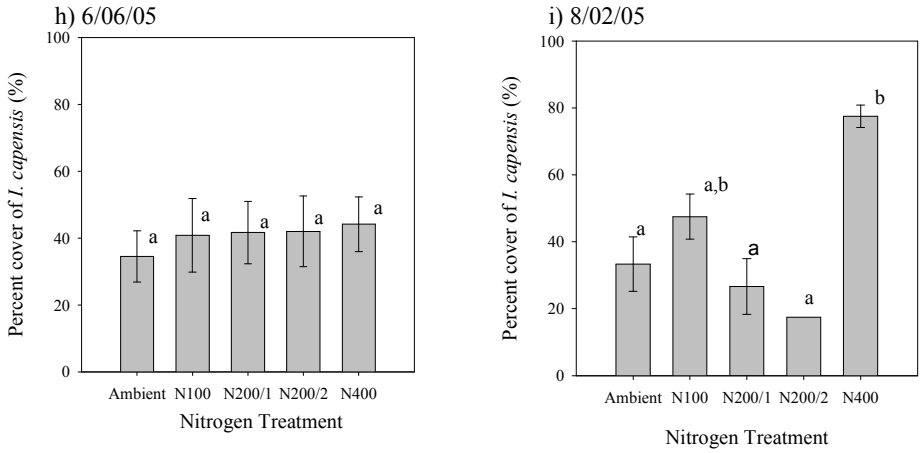
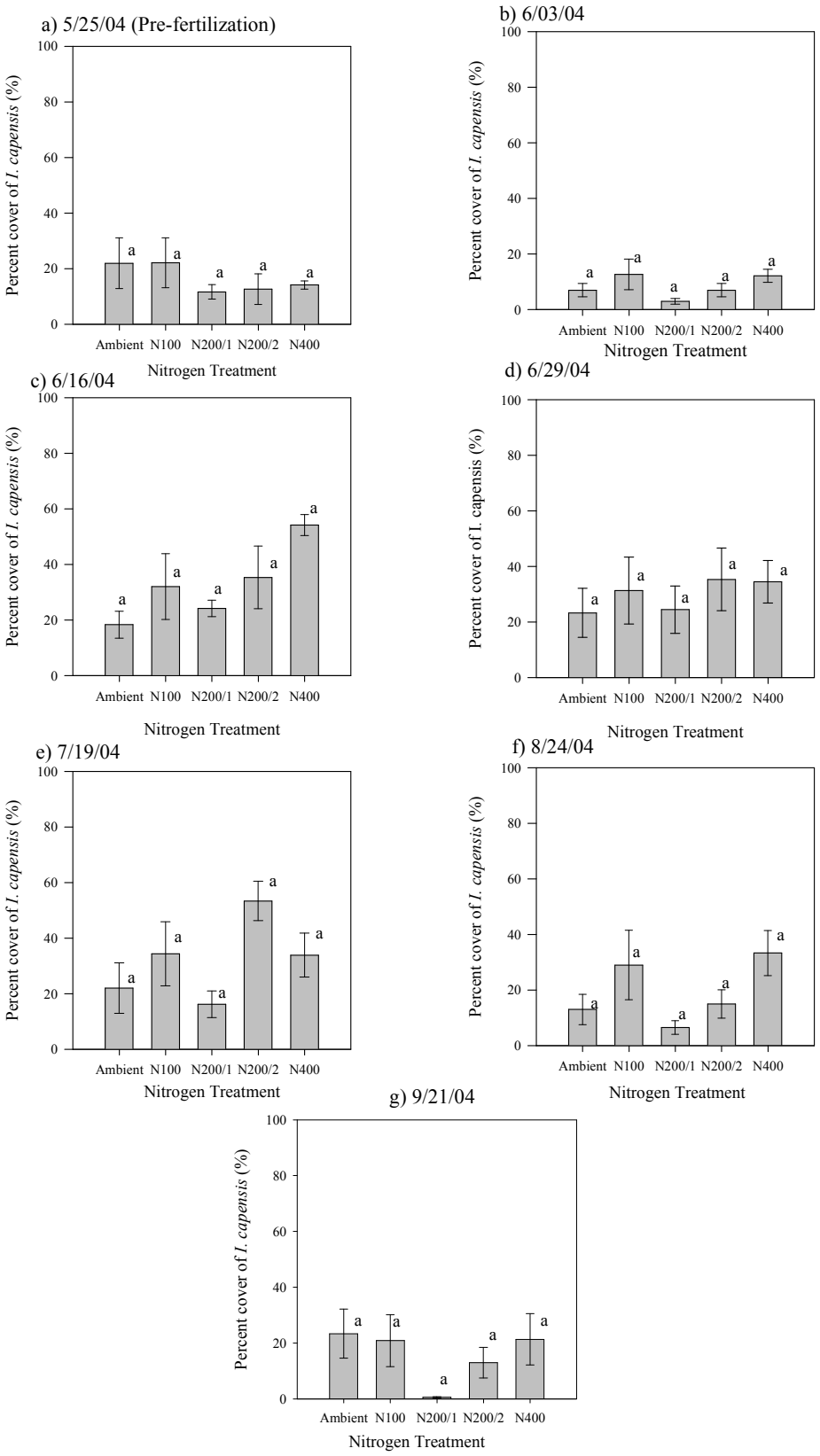



**Figure 3.2.17. Mean *I. capensis* percent cover and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *I. capensis* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

No nitrogen effects were discovered at the *Phragmites*-absent site for percent *I. capensis* in the 2004 growing season (Figure 3.2.18). However, in the 2005 growing season, sample date 6/06/05 showed that N400 had a significantly greater percent cover of *I. capensis* than all other treatments (Figure 3.2.18h).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of I. capensis (%)
Percent cover of I. capensis (%)
Ambient
N100
N200/1
N200/2
N400
Nitrogen Treatment
0
20
40
60
80
100
a

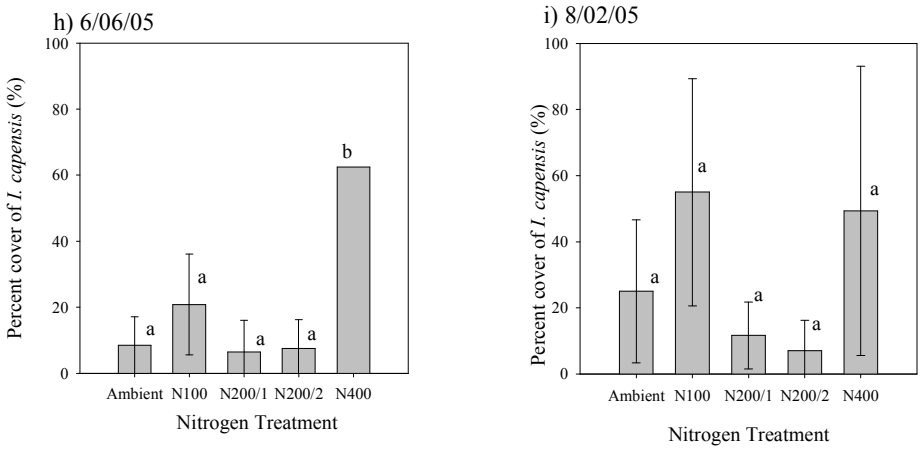



**Figure 3.2.18. Mean *I. capensis* percent cover and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent *I. capensis* was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on Leaf Area Index*

Leaf area index was analyzed to determine if it was affected by nitrogen fertilization. Since LAI appeared to be higher at the *Phragmites*-dominant site than at the *Phragmite*s-absent site, and both sites followed the same trend over time (Figure 3.2.19), site and time effects were evaluated before nitrogen effects were considered. Results indicated that there were strong site and time effects on LAI (Table 3.2.15), so nitrogen effects at individual sites and dates were evaluated. Time influenced LAI at the *Phragmites*-dominant site, but interacted with nitrogen effects at the *Phragmites*-absent site (Table 3.2.16). When individual dates were analyzed, site effects were detected on dates that had the lowest LAIs (Table 3.2.17 and Figure 3.2.19a). A nitrogen effect was revealed on 6/16/04 (Table 3.2.17), which was also the date that both sites had a high LAI (Figure 3.2.19a).

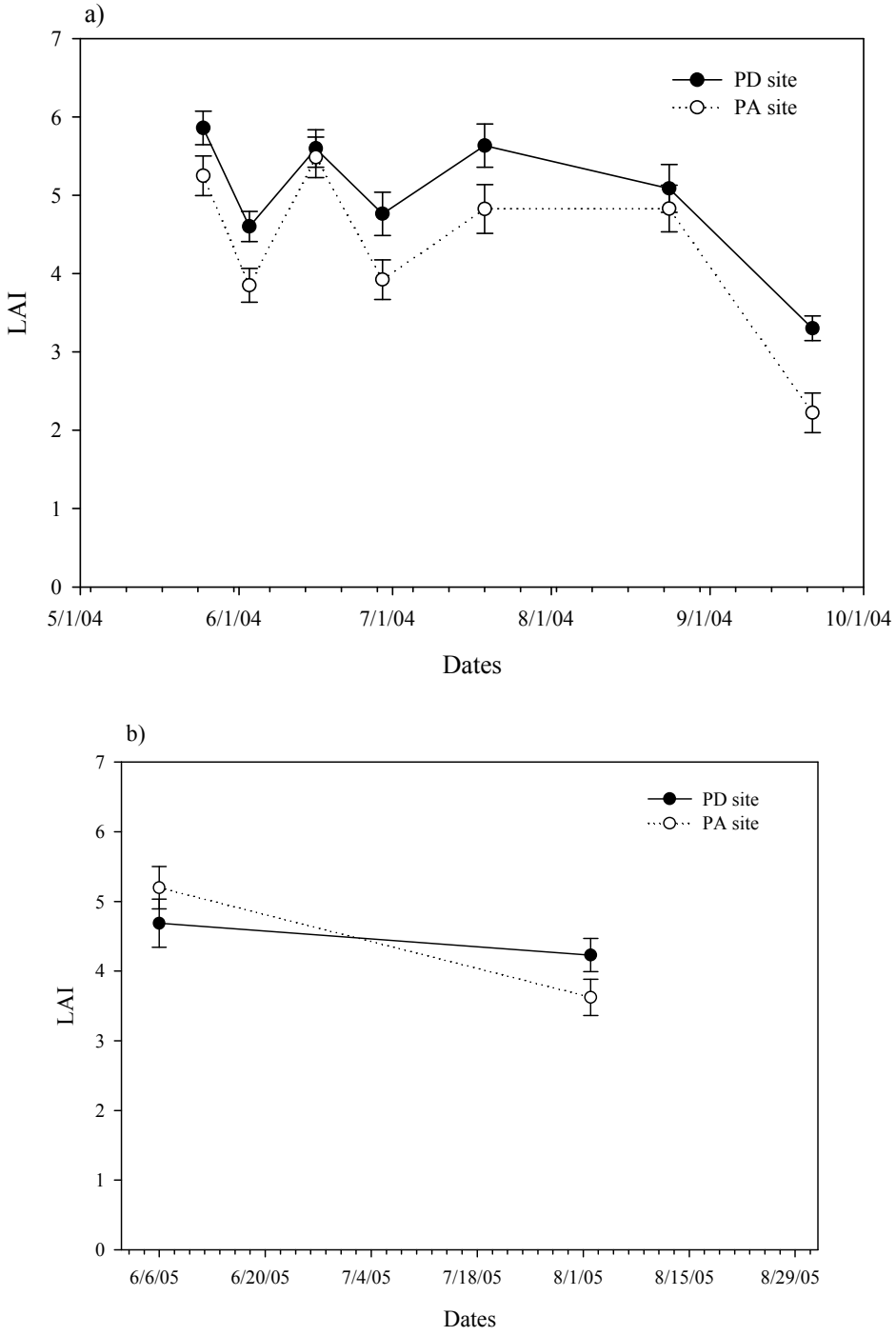



**Figure 3.2.19. Mean LAI and standard errors for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.15 Repeated measures ANOVA model for 2004 LAI. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 17.20 | 1 | 17.20 | 7.35 | 0.014** |
| Trt | 11.72 | 4 | 2.93 | 1.25 | 0.325 |
| Site * Trt | 11.25 | 4 | 2.81 | 1.20 | 0.344 |
| Error | 42.14 | 18 | 2.34 | | |
| Time | 160.71 | 6 | 26.79 | 38.08 | 0.000*** |
| Time * Site | 5.21 | 6 | 0.87 | 1.23 | 0.295 |
| Time * Trt | 17.45 | 24 | 0.73 | 1.03 | 0.431 |
| Time * Site * Trt | 18.09 | 24 | 0.75 | 1.07 | 0.388 |
| Error (time) | 75.96 | 108 | 0.70 | | |

**Table 3.2.16. ANOVA model: Trt + Time + (Trt*Time) at each marsh site for LAI. *** <0.01, ** < 0.05, * < 0.10**

| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 6.72 | 4 | 1.68 | 0.61 | 0.664 |
| | Time | 69.05 | 6 | 11.51 | 15.18 | 0.000*** |
| | Time * Trt | 6.83 | 24 | 0.28 | 0.38 | 0.995 |
| | Error | 45.48 | 60 | 0.76 | | |
| PA site | Trt | 16.95 | 4 | 4.24 | 2.32 | 0.145 |
| | Time | 94.55 | 6 | 15.76 | 24.82 | 0.000 |
| | Time * Trt | 27.21 | 24 | 1.13 | 1.79 | 0.044** |
| | Error | 30.48 | 48 | 0.64 | | |

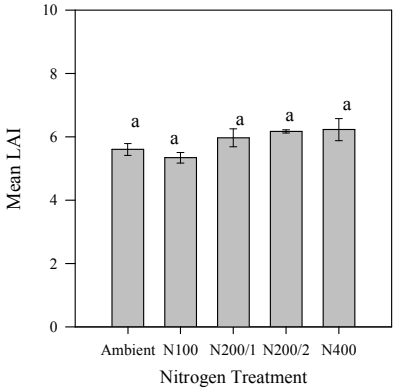
**Table 3.2.17 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for LAI. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 2.80 | 1 | 2.80 | 2.90 | 0.104 |
| | Trt | 2.23 | 4 | 0.56 | 0.58 | 0.683 |
| | Site * Trt | 1.78 | 4 | 0.44 | 0.46 | 0.764 |
| | Error | 19.31 | 20 | 0.97 | | |
| 6/3/2004 | Site | 3.43 | 1 | 3.43 | 6.13 | 0.023** |
| | Trt | 4.18 | 4 | 1.05 | 1.87 | 0.158 |
| | Site * Trt | 2.35 | 4 | 0.59 | 1.05 | 0.409 |
| | Error | 10.65 | 19 | 0.56 | | |
| 6/16/2004 | Site | 0.10 | 1 | 0.10 | 0.13 | 0.726 |
| | Trt | 7.17 | 4 | 1.79 | 2.35 | 0.089* |
| | Site * Trt | 3.55 | 4 | 0.89 | 1.16 | 0.356 |
| | Error | 15.24 | 20 | 0.76 | | |

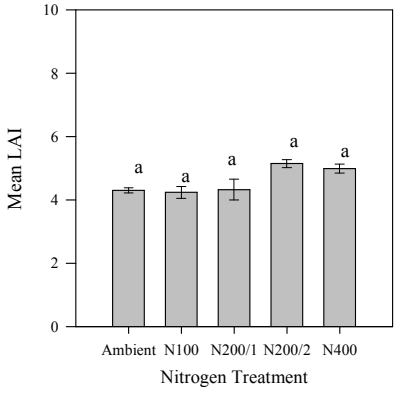
| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 5.29 | 1 | 5.29 | 5.32 | 0.032** |
| | Trt | 3.09 | 4 | 0.77 | 0.78 | 0.553 |
| | Site * Trt | 6.33 | 4 | 1.58 | 1.59 | 0.215 |
| | Error | 19.88 | 20 | 0.99 | | |
| 7/19/2004 | Site | 4.90 | 1 | 4.90 | 5.73 | 0.027 |
| | Trt | 7.81 | 4 | 1.95 | 2.28 | 0.096 |
| | Site * Trt | 11.45 | 4 | 2.86 | 3.34 | 0.030** |
| | Error | 17.12 | 20 | 0.86 | | |
| 8/24/2004 | Site | 0.53 | 1 | 0.53 | 0.37 | 0.548 |
| | Trt | 2.95 | 4 | 0.74 | 0.52 | 0.720 |
| | Site * Trt | 7.10 | 4 | 1.77 | 1.26 | 0.322 |
| | Error | 26.85 | 19 | 1.41 | | |
| 9/21/2004 | Site | 8.73 | 1 | 8.73 | 11.23 | 0.003*** |
| | Trt | 2.84 | 4 | 0.71 | 0.91 | 0.475 |
| | Site * Trt | 0.28 | 4 | 0.07 | 0.09 | 0.984 |
| | Error | 15.54 | 20 | 0.78 | | |
| 6/6/2005 | Site | 1.95 | 1 | 1.95 | 1.47 | 0.239 |
| | Trt | 11.56 | 4 | 2.89 | 2.18 | 0.108 |
| | Site * Trt | 6.30 | 4 | 1.57 | 1.19 | 0.347 |
| | Error | 26.52 | 20 | 1.33 | | |
| 8/2/2005 | Site | 2.75 | 1 | 2.75 | 2.65 | 0.119 |
| | Trt | 3.06 | 4 | 0.77 | 0.74 | 0.577 |
| | Site * Trt | 2.38 | 4 | 0.59 | 0.57 | 0.685 |
| | Error | 20.76 | 20 | 1.04 | | |

Nitrogen effects on LAI were analyzed at individual sites and dates so site and time effects would not interfere with treatment effects. Leaf area index was not affected by nitrogen on any date at the *Phragmites*-dominant site (Figure 3.2.20). All treatments had very uniform LAIs across treatments for both the 2004 and 2005 growing seasons.

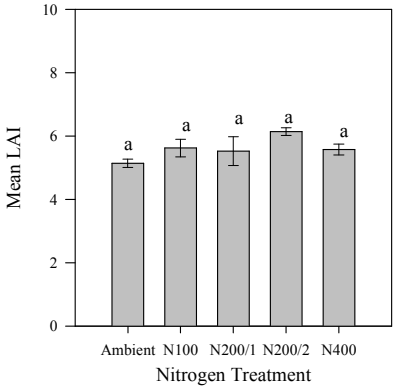
a) 5/25/04 (Pre-fertilization)



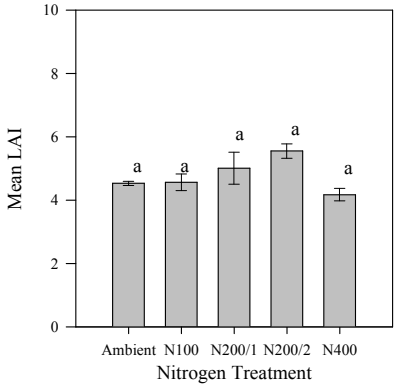

b) 6/03/04



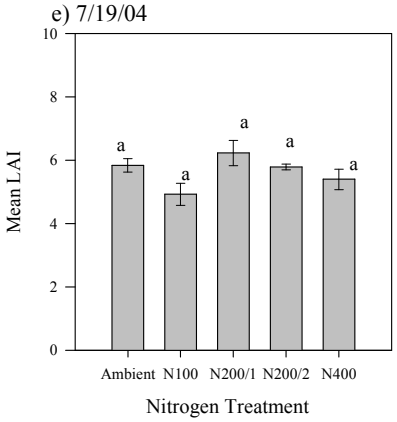

c) 6/16/04



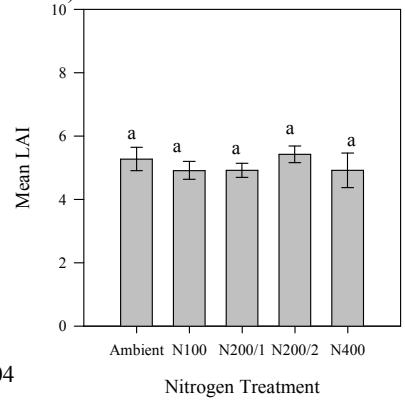

d) 6/29/04



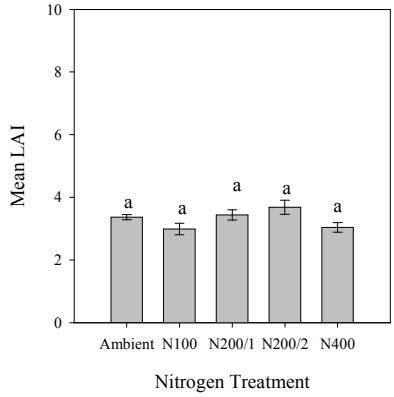

e) 7/19/04




f) 8/24/04




g) 9/21/04



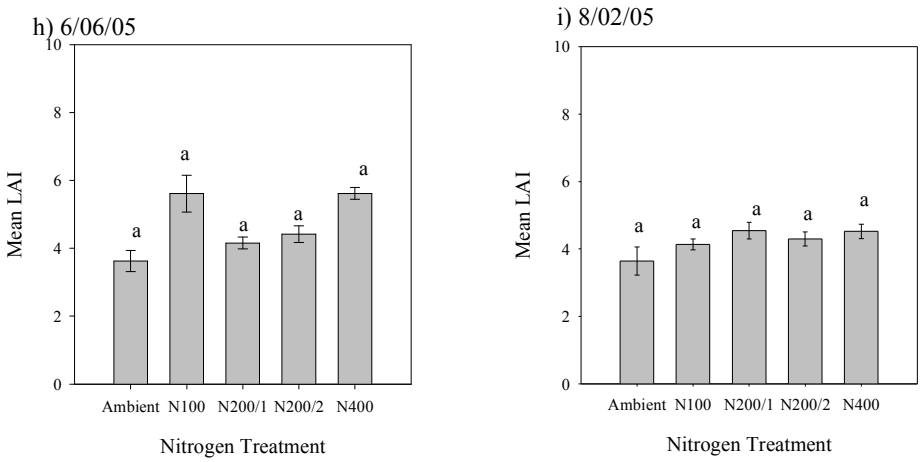
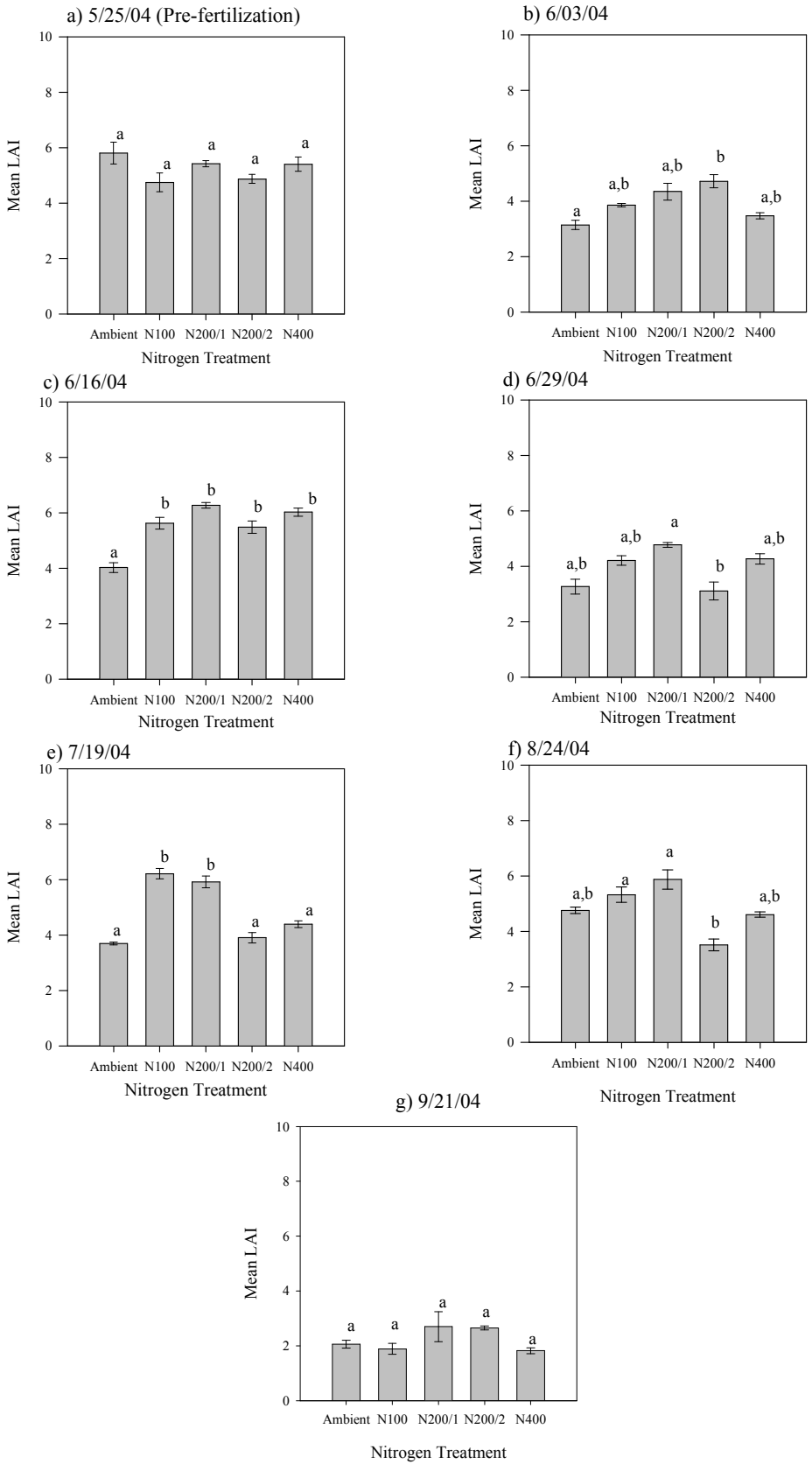



**Figure 3.2.20. Mean LAI and standard errors at the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). LAI was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

At the *Phragmites*-absent site, additional nitrogen appeared to increase LAI during the early growing season (Figure 3.2.21), but the effect disappeared by September. Sample dates in 2005 showed no significant treatment effects (Figures 3.2.21h and 3.2.21i).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Mean LAI
Ambient N100 N200/1 N200/2 N400
Nitrogen Treatment

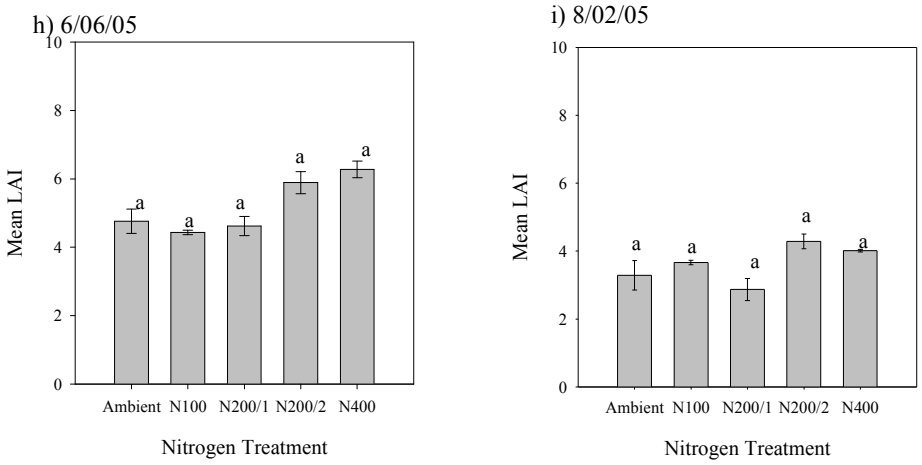



**Figure 3.2.21. Mean LAI and standard errors at the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). LAI was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on Species Richness*

Nitrogen effects on species richness were analyzed after both site and time effects were evaluated. Figure 3.2.22 shows the progression of species richness at each site over the season. Both sites had 6 – 8 species present for the majority of the summer until late August when species began to senesce. Upon analysis, it was established that site and time interacted to affect species richness (Table 3.2.18). Time and treatment were evaluated at each site, revealing a strong time effect on species richness (Table 3.2.19). When time effects were eliminated by analyzing site and nitrogen effects at every date, a nitrogen effect was distinguished on 6/29/04 when sites had similar species richness and site effects were expectedly noted on dates that had the most difference between species richness (Table 3.2.20 and Figure 3.2.22a).

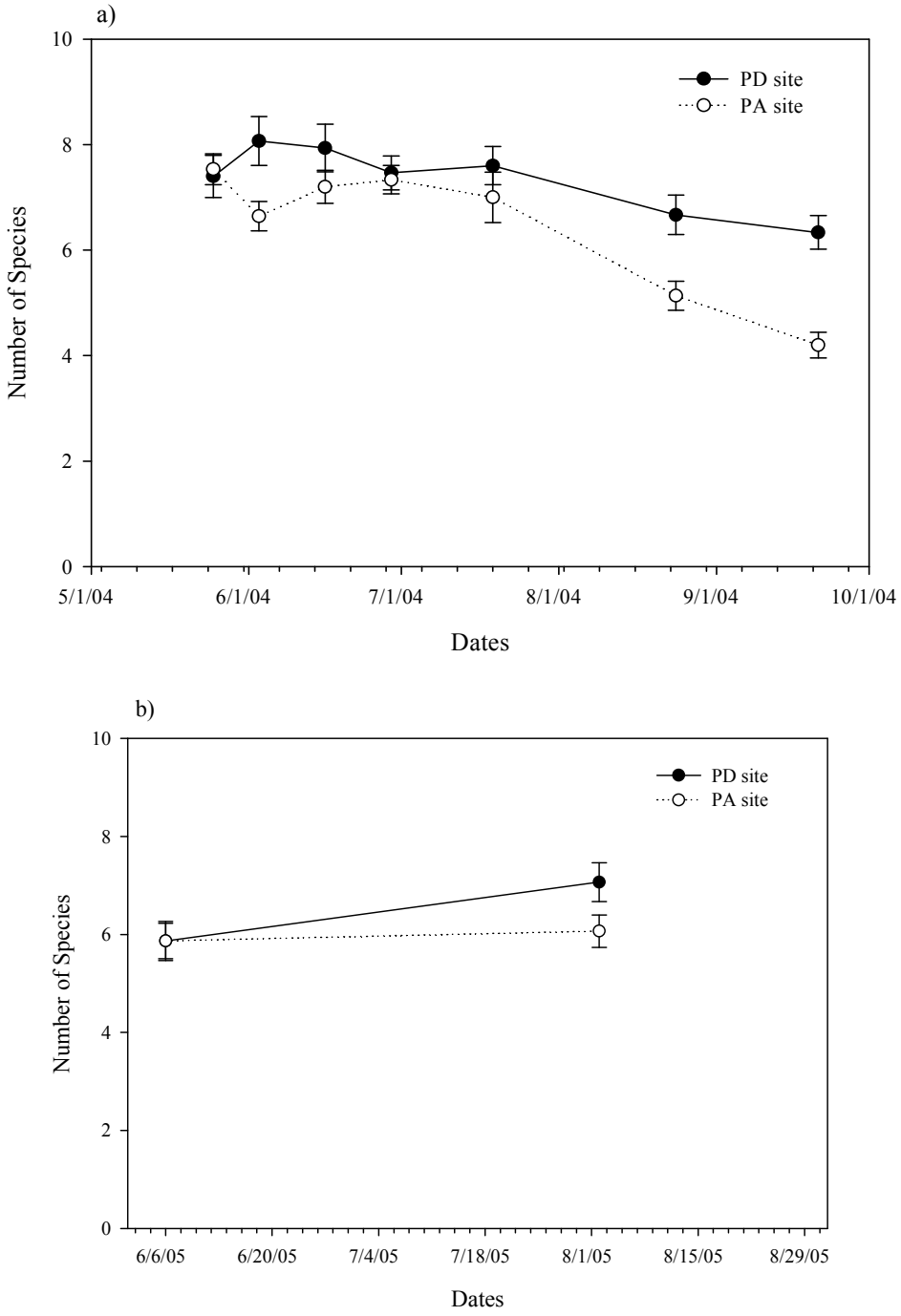



**Figure 3.2.22. Mean number of species and standard errors for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.18 Repeated measures ANOVA model for 2004 species richness. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 54.38 | 1 | 54.38 | 11.51 | 0.003 |
| Trt | 50.99 | 4 | 12.75 | 2.70 | 0.062 |
| Site * Trt | 26.52 | 4 | 6.63 | 1.40 | 0.271 |
| Error | 89.79 | 19 | 4.73 | | |
| Time | 139.32 | 6 | 23.22 | 21.51 | 0.000 |
| Time * Site | 24.88 | 6 | 4.15 | 3.84 | 0.002*** |
| Time * Trt | 16.51 | 24 | 0.69 | 0.64 | 0.899 |
| Time * Site * Trt | 19.15 | 24 | 0.80 | 0.74 | 0.801 |
| Error (time) | 123.05 | 114 | 1.08 | | |

**Table 3.2.19 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for species richness. *** <0.01, ** < 0.05, * < 0.10**

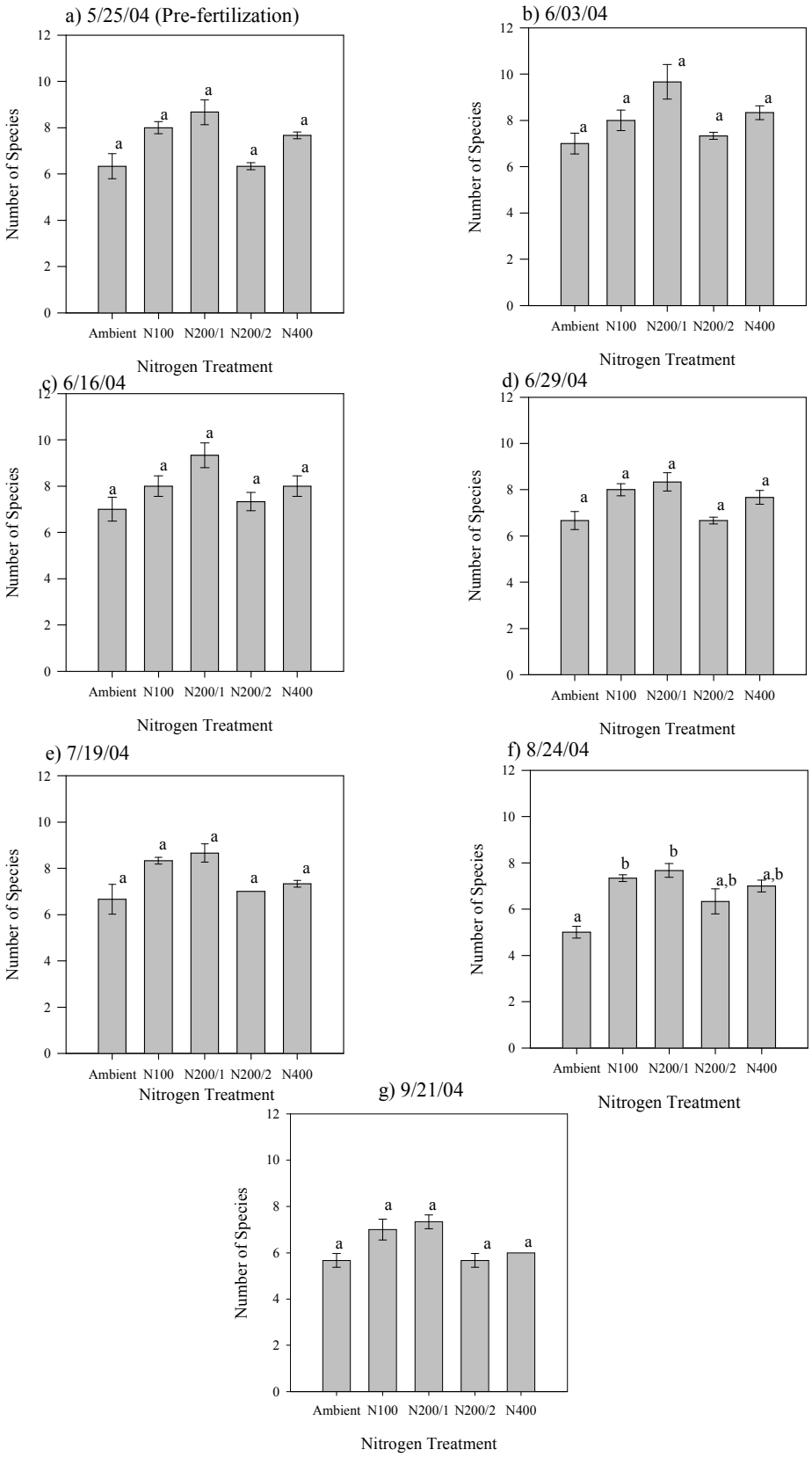
| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 65.01 | 4 | 16.25 | 2.14 | 0.150 |
| | Time | 36.50 | 6 | 6.08 | 4.96 | 0.000*** |
| | Time * Trt | 7.12 | 24 | 0.30 | 0.24 | 1.000 |
| | Error | 73.52 | 60 | 1.23 | | |
| PA site | Trt | 14.44 | 4 | 3.61 | 2.33 | 0.135 |
| | Time | 123.57 | 6 | 20.59 | 22.46 | 0.000*** |
| | Time * Trt | 27.41 | 24 | 1.14 | 1.25 | 0.248 |
| | Error | 49.52 | 54 | 0.92 | | |

**Table 3.2.20 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for species richness. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 0.13 | 1 | 0.13 | 0.07 | 0.788 |
| | Trt | 9.13 | 4 | 2.28 | 1.27 | 0.315 |
| | Site * Trt | 6.20 | 4 | 1.55 | 0.86 | 0.504 |
| | Error | 36.00 | 20 | 1.80 | | |
| 6/3/2004 | Site | 14.67 | 1 | 14.67 | 6.17 | 0.022** |
| | Trt | 9.97 | 4 | 2.49 | 1.05 | 0.409 |
| | Site * Trt | 4.69 | 4 | 1.17 | 0.49 | 0.741 |
| | Error | 45.17 | 19 | 2.38 | | |
| 6/16/2004 | Site | 4.03 | 1 | 4.03 | 1.95 | 0.178 |
| | Trt | 15.87 | 4 | 3.97 | 1.92 | 0.146 |
| | Site * Trt | 6.13 | 4 | 1.53 | 0.74 | 0.575 |
| | Error | 41.33 | 20 | 2.07 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 0.13 | 1 | 0.13 | 0.12 | 0.735 |
| | Trt | 10.87 | 4 | 2.72 | 2.40 | 0.084* |
| | Site * Trt | 3.53 | 4 | 0.88 | 0.78 | 0.552 |
| | Error | 22.67 | 20 | 1.13 | | |
| 7/19/2004 | Site | 2.70 | 1 | 2.70 | 1.45 | 0.243 |
| | Trt | 15.80 | 4 | 3.95 | 2.12 | 0.117 |
| | Site * Trt | 22.47 | 4 | 5.62 | 3.01 | 0.043** |
| | Error | 37.33 | 20 | 1.87 | | |
| 8/24/2004 | Site | 17.63 | 1 | 17.63 | 13.23 | 0.002 |
| | Trt | 4.20 | 4 | 1.05 | 0.79 | 0.547 |
| | Site * Trt | 14.20 | 4 | 3.55 | 2.66 | 0.063* |
| | Error | 26.67 | 20 | 1.33 | | |
| 9/21/2004 | Site | 34.13 | 1 | 34.13 | 27.68 | 0.000*** |
| | Trt | 1.53 | 4 | 0.38 | 0.31 | 0.867 |
| | Site * Trt | 7.53 | 4 | 1.88 | 1.53 | 0.232 |
| | Error | 24.67 | 20 | 1.23 | | |
| 6/6/2005 | Site | 0.00 | 1 | 0.00 | 0.00 | 1.000 |
| | Trt | 11.47 | 4 | 2.87 | 1.32 | 0.296 |
| | Site * Trt | 6.67 | 4 | 1.67 | 0.77 | 0.558 |
| | Error | 43.33 | 20 | 2.17 | | |
| 8/2/2005 | Site | 7.50 | 1 | 7.50 | 3.52 | 0.075* |
| | Trt | 1.53 | 4 | 0.38 | 0.18 | 0.946 |
| | Site * Trt | 11.67 | 4 | 2.92 | 1.37 | 0.281 |
| | Error | 42.67 | 20 | 2.13 | | |

Since site and time effects on species richness were both present, nitrogen effects were further analyzed on individual sites at each sample date. At the *Phragmites*-dominant site, the number of species present across the growing season was not affected by nitrogen fertilization for the majority of the 2004-5 seasons (Figure 3.2.23). Only on the 8/24/04 did nitrogen addition appear to increase species richness over the control (Figure 3.2.23f).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Number of Species
Nitrogen Treatment
Ambient N100 N200/1 N200/2 N400
0 2 4 6 8 10 12
a
a,b
b

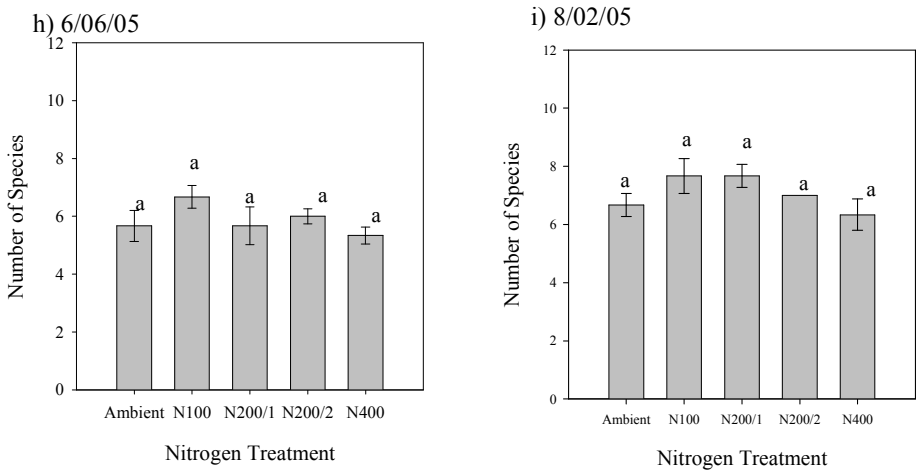
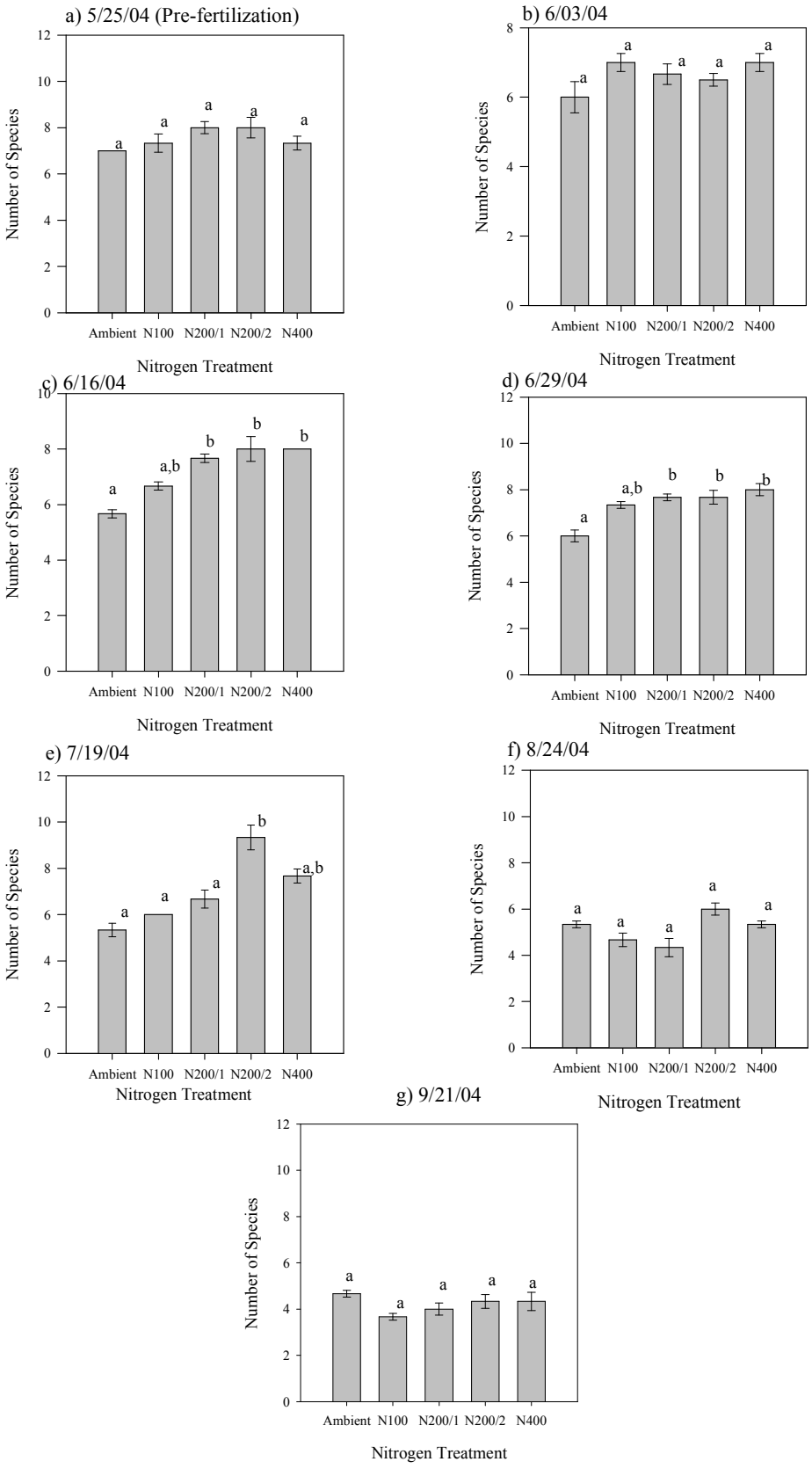



**Figure 3.2.23. Mean species richness and standard errors at the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Species richness was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

At the *Phragmites*-absent site the addition of nitrogen increased species richness early in the growing season (mid-June – July) but the effect disappeared by August (Figure 3.2.24). From mid-June through mid-July, the middle nitrogen fertilizer treatments (N200/1D and N200/2D) yielded significantly more species than ambient conditions (Figure 3.2.24c-e). N200/2D also produced higher species richness on 6/06/05 (Figure 3.2.24h).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Number of Species
Ambient N100 N200/1 N200/2 N400
Nitrogen Treatment

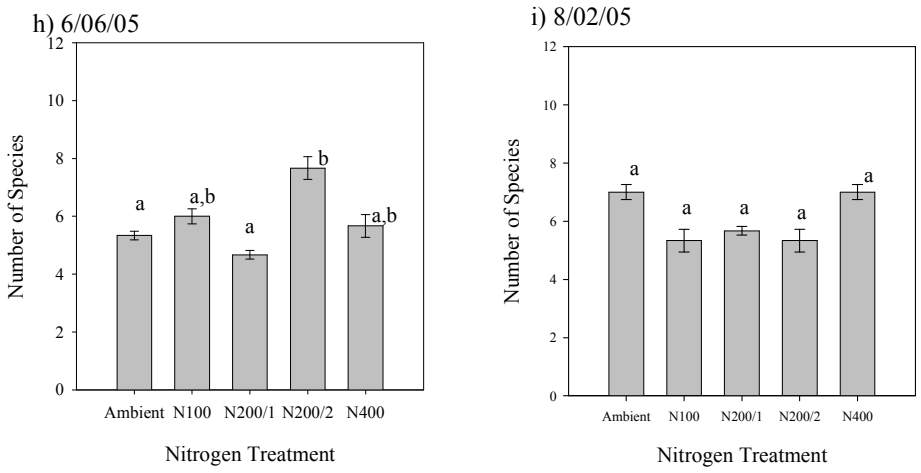



**Figure 3.2.24. Mean species richness and standard errors at the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Species richness was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on dead material*

Nitrogen fertilization effect on percent cover of dead material in the marsh was analyzed by first investigating site and time effects. The site effect on percent dead material cover over time, illustrated in Figure 3.2.25, was found to interact with the time effect (Table 3.2.21), so nitrogen effects were analyzed with time at individual sites and with site on each date. Time effects on percent dead material cover were highly significant at both sites and nitrogen effects were discovered at the *Phragmites*-dominant site (Table 3.2.22). Site effects on dead material percent cover were found for the majority of the growing season, while nitrogen effects were not detected on any date (Table 3.2.23).

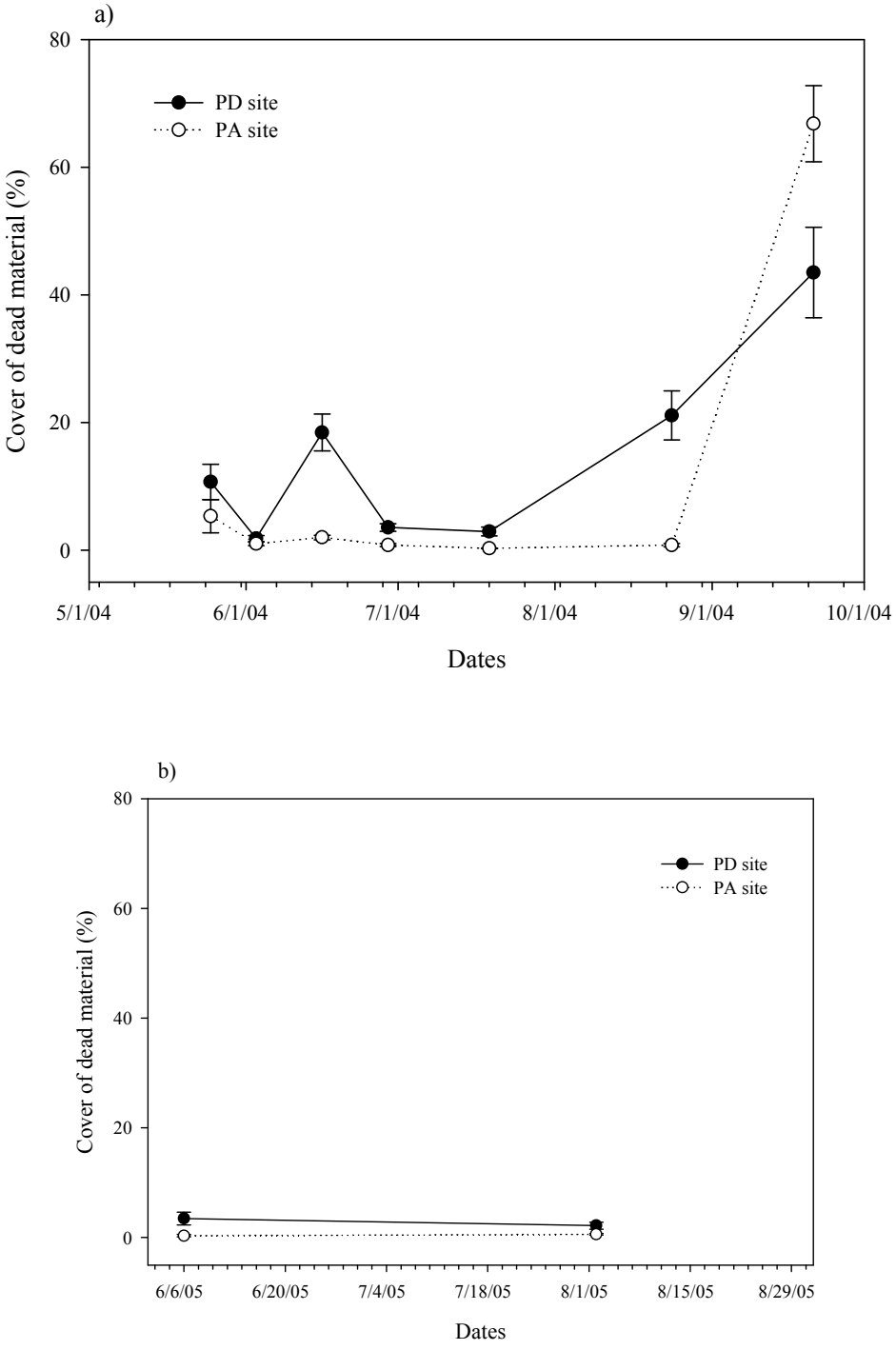



**Figure 3.2.25. Mean percent cover of dead material and standard errors for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.21 Repeated measures ANOVA model for 2004 percent dead material. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 671.61 | 1 | 671.61 | 4.68 | 0.043 |
| Trt | 1615.37 | 4 | 403.84 | 2.81 | 0.053 |
| Site * Trt | 960.34 | 4 | 240.09 | 1.67 | 0.196 |
| Error | 2870.76 | 20 | 143.54 | | |
| Time | 65863.92 | 6 | 10977.32 | 86.68 | 0.000 |
| Time * Site | 8864.38 | 6 | 1477.40 | 11.67 | 0.000*** |
| Time * Trt | 3612.48 | 24 | 150.52 | 1.19 | 0.266 |
| Time * Site * Trt | 1974.80 | 24 | 82.28 | 0.65 | 0.889 |
| Error (time) | 15197.85 | 120 | 126.65 | | |

**Table 3.2.22 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for dead material. *** <0.01, ** < 0.05, * < 0.10**

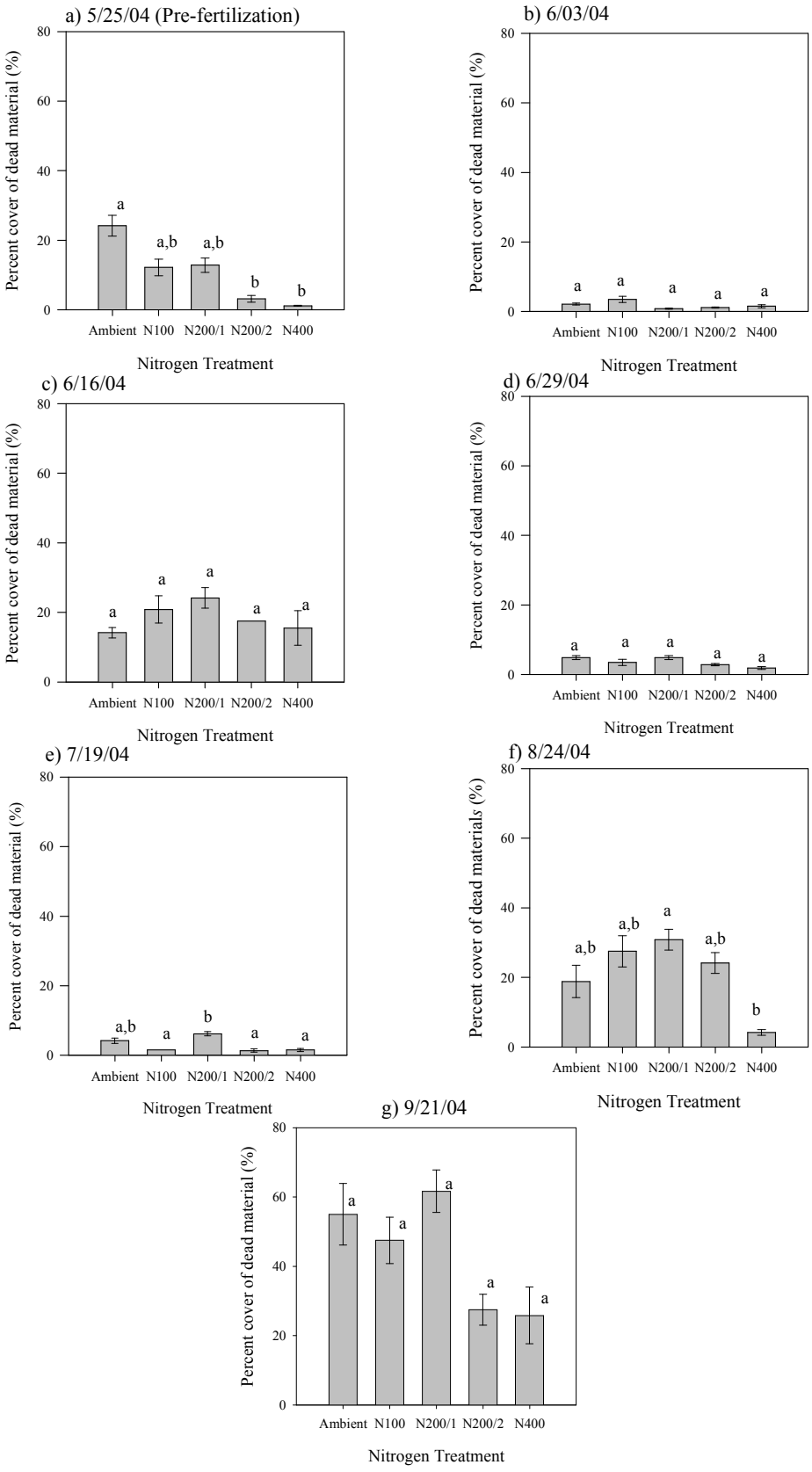
| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 2294.57 | 4 | 573.64 | 2.69 | 0.093* |
| | Time | 19921.76 | 6 | 3320.29 | 21.20 | 0.000*** |
| | Time * Trt | 3450.90 | 24 | 143.79 | 0.92 | 0.578 |
| | Error | 9395.58 | 60 | 156.59 | | |
| PA site | Trt | 281.14 | 4 | 70.28 | 0.96 | 0.472 |
| | Time | 54806.53 | 6 | 9134.42 | 94.46 | 0.000*** |
| | Time * Trt | 2136.38 | 24 | 89.02 | 0.92 | 0.576 |
| | Error | 5802.27 | 60 | 96.70 | | |

**Table 3.2.23 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for percent dead material. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 215.74 | 1 | 215.74 | 2.50 | 0.129 |
| | Trt | 353.37 | 4 | 88.34 | 1.03 | 0.418 |
| | Site * Trt | 943.79 | 4 | 235.95 | 2.74 | 0.058* |
| | Error | 1723.54 | 20 | 86.18 | | |
| 6/3/2004 | Site | 5.13 | 1 | 5.13 | 2.15 | 0.158 |
| | Trt | 5.03 | 4 | 1.26 | 0.53 | 0.717 |
| | Site * Trt | 12.37 | 4 | 3.09 | 1.30 | 0.305 |
| | Error | 47.74 | 20 | 2.39 | | |
| 6/16/2004 | Site | 2025.41 | 1 | 2025.41 | 25.93 | 0.000*** |
| | Trt | 111.80 | 4 | 27.95 | 0.36 | 0.836 |
| | Site * Trt | 94.47 | 4 | 23.62 | 0.30 | 0.873 |
| | Error | 1562.17 | 20 | 78.11 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 57.96 | 1 | 57.96 | 18.58 | 0.000*** |
| | Trt | 11.07 | 4 | 2.77 | 0.89 | 0.490 |
| | Site * Trt | 12.44 | 4 | 3.11 | 1.00 | 0.432 |
| | Error | 62.41 | 20 | 3.12 | | |
| 7/19/2004 | Site | 52.67 | 1 | 52.67 | 24.45 | 0.000 |
| | Trt | 29.16 | 4 | 7.29 | 3.38 | 0.029 |
| | Site * Trt | 26.69 | 4 | 6.67 | 3.10 | 0.039** |
| | Error | 43.08 | 20 | 2.15 | | |
| 8/24/2004 | Site | 3095.75 | 1 | 3095.75 | 34.15 | 0.000*** |
| | Trt | 609.92 | 4 | 152.48 | 1.68 | 0.194 |
| | Site * Trt | 703.72 | 4 | 175.93 | 1.94 | 0.143 |
| | Error | 1813.02 | 20 | 90.65 | | |
| 9/21/2004 | Site | 4083.33 | 1 | 4083.33 | 6.37 | 0.020** |
| | Trt | 4107.50 | 4 | 1026.88 | 1.60 | 0.213 |
| | Site * Trt | 1141.67 | 4 | 285.42 | 0.45 | 0.774 |
| | Error | 12816.67 | 20 | 640.83 | | |
| 6/6/2005 | Site | 73.48 | 1 | 73.48 | 10.06 | 0.005 |
| | Trt | 75.23 | 4 | 18.81 | 2.58 | 0.069 |
| | Site * Trt | 76.87 | 4 | 19.22 | 2.63 | 0.065* |
| | Error | 146.06 | 20 | 7.30 | | |
| 8/2/2005 | Site | 19.04 | 1 | 19.04 | 5.21 | 0.034** |
| | Trt | 10.53 | 4 | 2.63 | 0.72 | 0.588 |
| | Site * Trt | 6.48 | 4 | 1.62 | 0.44 | 0.776 |
| | Error | 73.11 | 20 | 3.66 | | |

Since nitrogen effects on percent dead material cover were sensitive to time and site, the effect of nitrogen was analyzed on individual dates at each site. At the *Phragmites*-dominant site, percent dead material for N400 was lower than other treatments in July and August (Figure 3.2.26e and f).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of dead material (%)
Percent cover of dead materials (%)
0
20
40
60
80
a
a,b
b
Ambient
N100
N200/1
N200/2
N400
Nitrogen Treatment

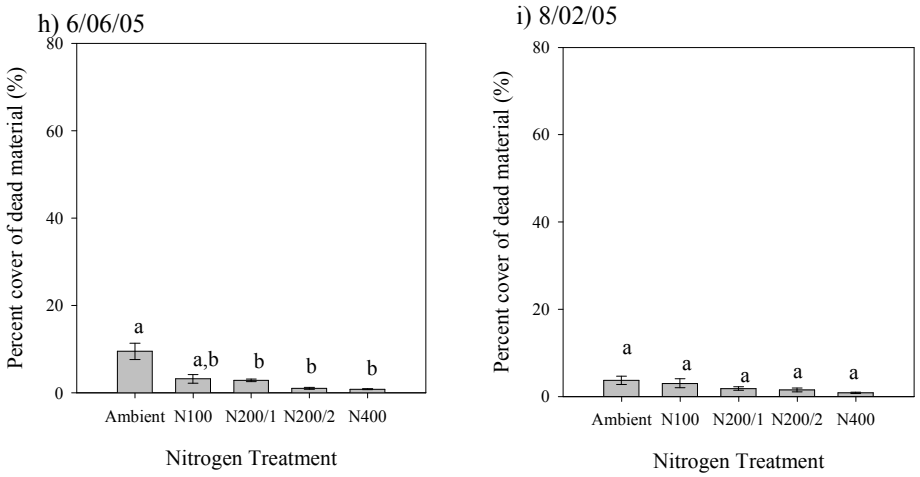
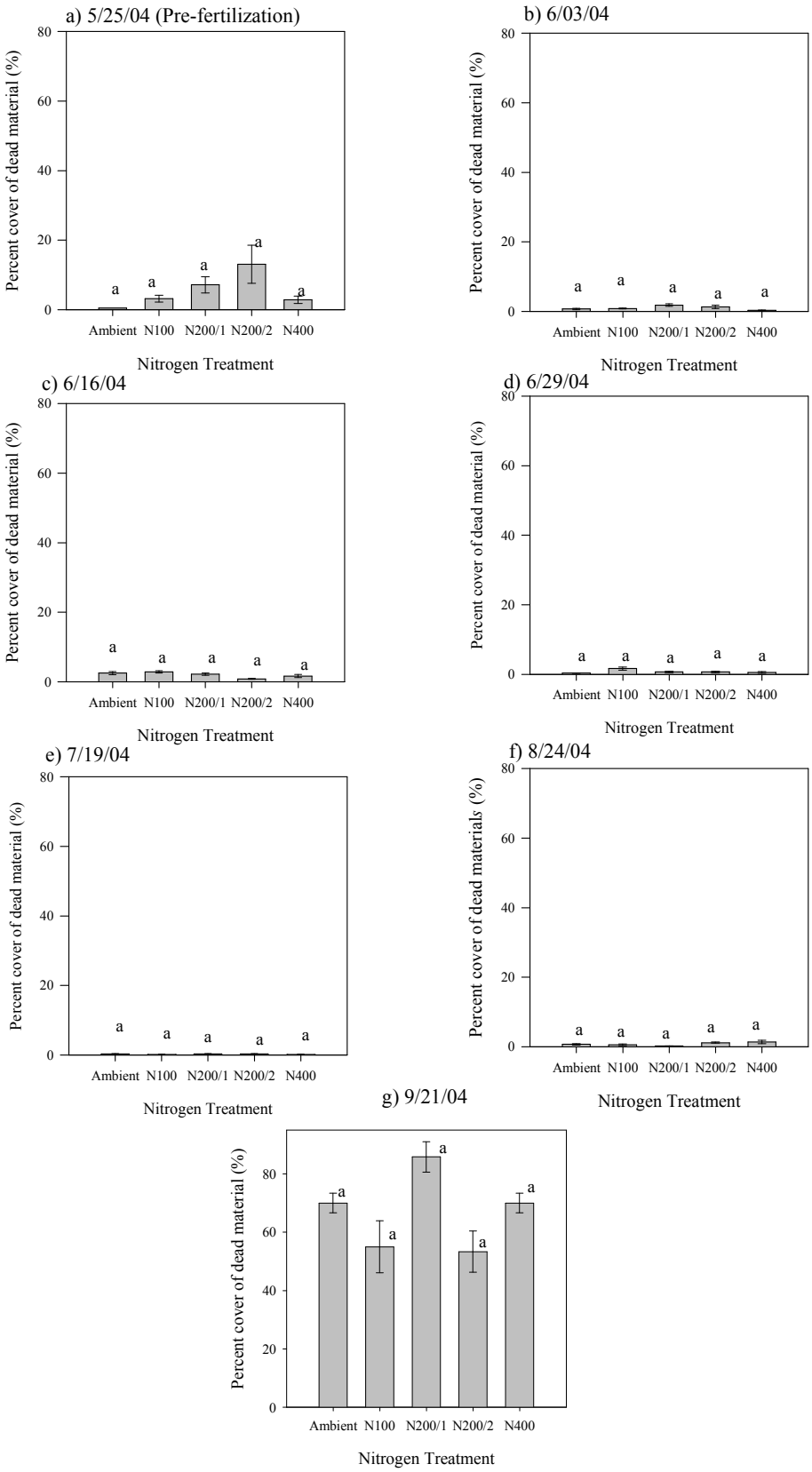



**Figure 3.2.26. Mean percent dead material and standard errors at the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent dead material was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

At the *Phragmites*-absent site, no nitrogen effects existed for percent dead material cover on any date in 2004 or 2005 (Figure 3.2.27). Percent cover of dead material followed the same pattern across time for all treatments, where very little dead matter existed during the growing season until September when percent mean reached approximately 60%.


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Percent cover of dead material (%)
Percent cover of dead materials (%)
0
20
40
60
80
a
Ambient
N100
N200/1
N200/2
N400
Nitrogen Treatment

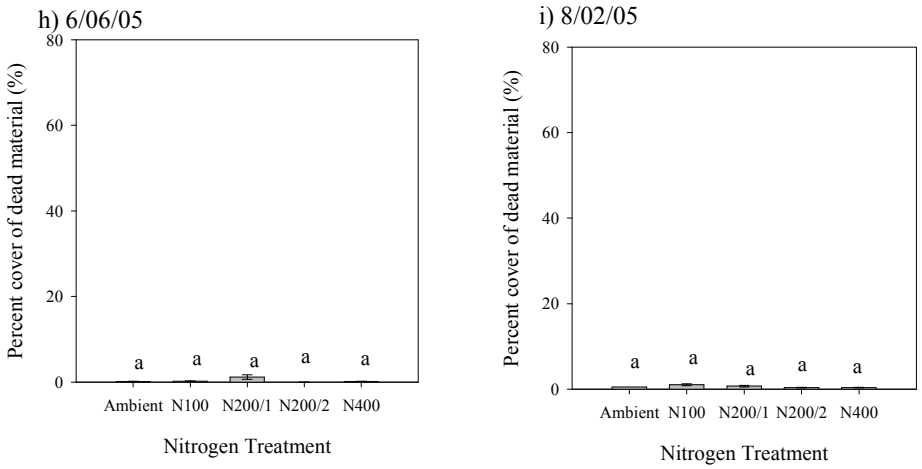



**Figure 3.2.27. Mean percent dead material and standard errors at the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Percent dead material was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on Shannon-Wiener Diversity Index*

The Shannon-Wiener diversity index was evaluated for nitrogen effects, as well as site and time effects for the 2004-5 growing seasons. The *Phragmites*-dominant site visually had a higher Shannon-Wiener species diversity index than the *Phragmites*-absent site and retained a high diversity index for the majority of the 2004 season, while the *Phragmites*-absent site's diversity index fell to below a value of 1.0 in mid-July (Figure 3.2.28). The visual differences between sites and sample dates were statistically proven with an interaction effect between site and time (Table 3.2.24). Analysis of time and treatment at each site found a strong time effect at both sites (Table 3.2.25). Analysis of site and treatment at each date found a site effect at the majority of sample dates, particularly those near the end of the growing season (Table 3.2.26). Also, a minor nitrogen effect on diversity index was found early in the 2004 season, on 6/03/04 and 6/16/04 (Table 3.2.26).

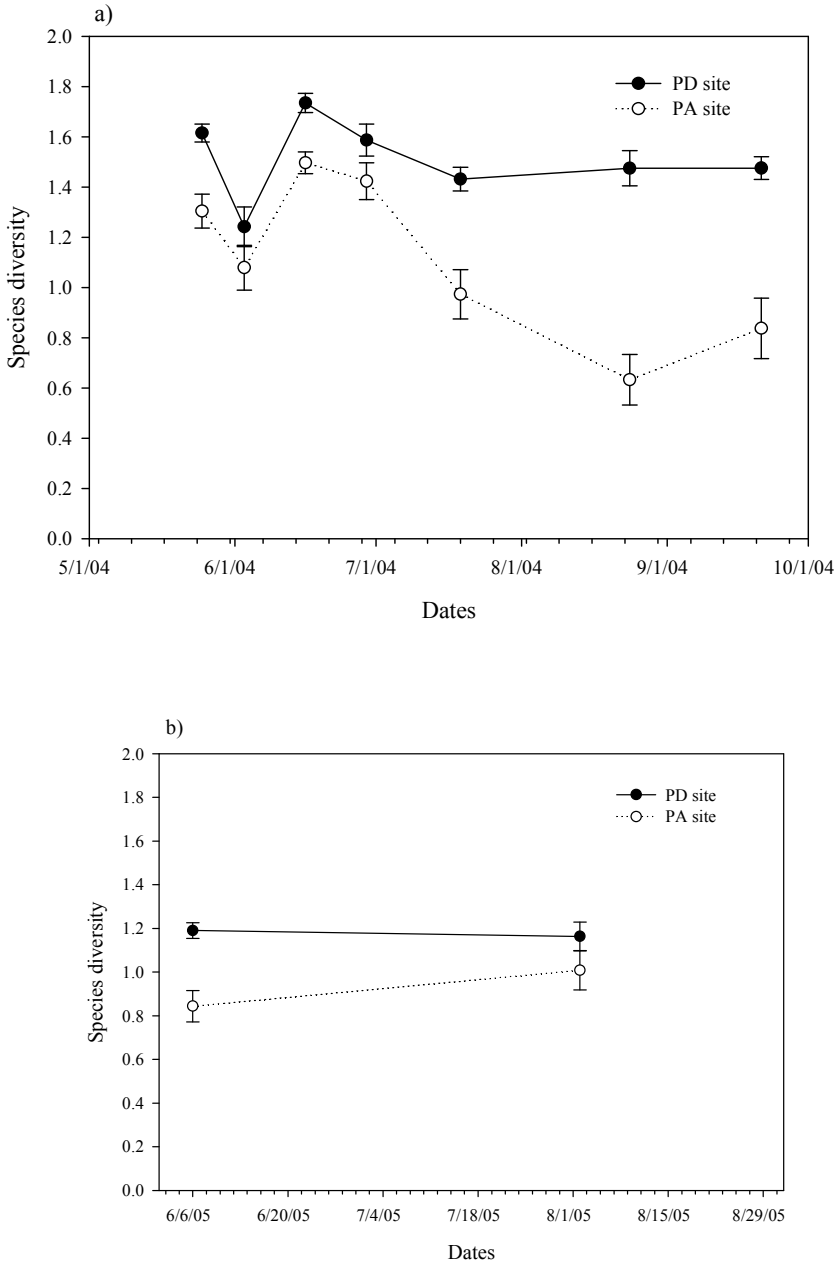



**Figure 3.2.28. Mean Shannon-Wiener diversity and standard errors for the *Phragmites*-dominant and *Phragmites*-absent sites across the (a) 2004 and (b) 2005 growing seasons.**

**Table 3.2.24 Repeated measures ANOVA model for 2004 Shannon-Wiener diversity index. *** <0.01, ** < 0.05, * < 0.10**

| Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|
| Site | 8.72 | 1 | 8.72 | 59.65 | 0.000 |
| Trt | 0.83 | 4 | 0.21 | 1.42 | 0.266 |
| Site * Trt | 0.91 | 4 | 0.23 | 1.55 | 0.228 |
| Error | 2.78 | 19 | 0.15 | | |
| Time | 7.58 | 6 | 1.26 | 20.34 | 0.000 |
| Time * Site | 2.69 | 6 | 0.45 | 7.23 | 0.000*** |
| Time * Trt | 1.13 | 24 | 0.05 | 0.76 | 0.780 |
| Time * Site * Trt | 1.72 | 24 | 0.07 | 1.15 | 0.300 |
| Error (time) | 7.08 | 114 | 0.06 | | |

**Table 3.2.25 ANOVA model: Trt + Time + (Trt*Time) at each marsh site for Shannon-Wiener diversity index. *** <0.01, ** < 0.05, * < 0.10**

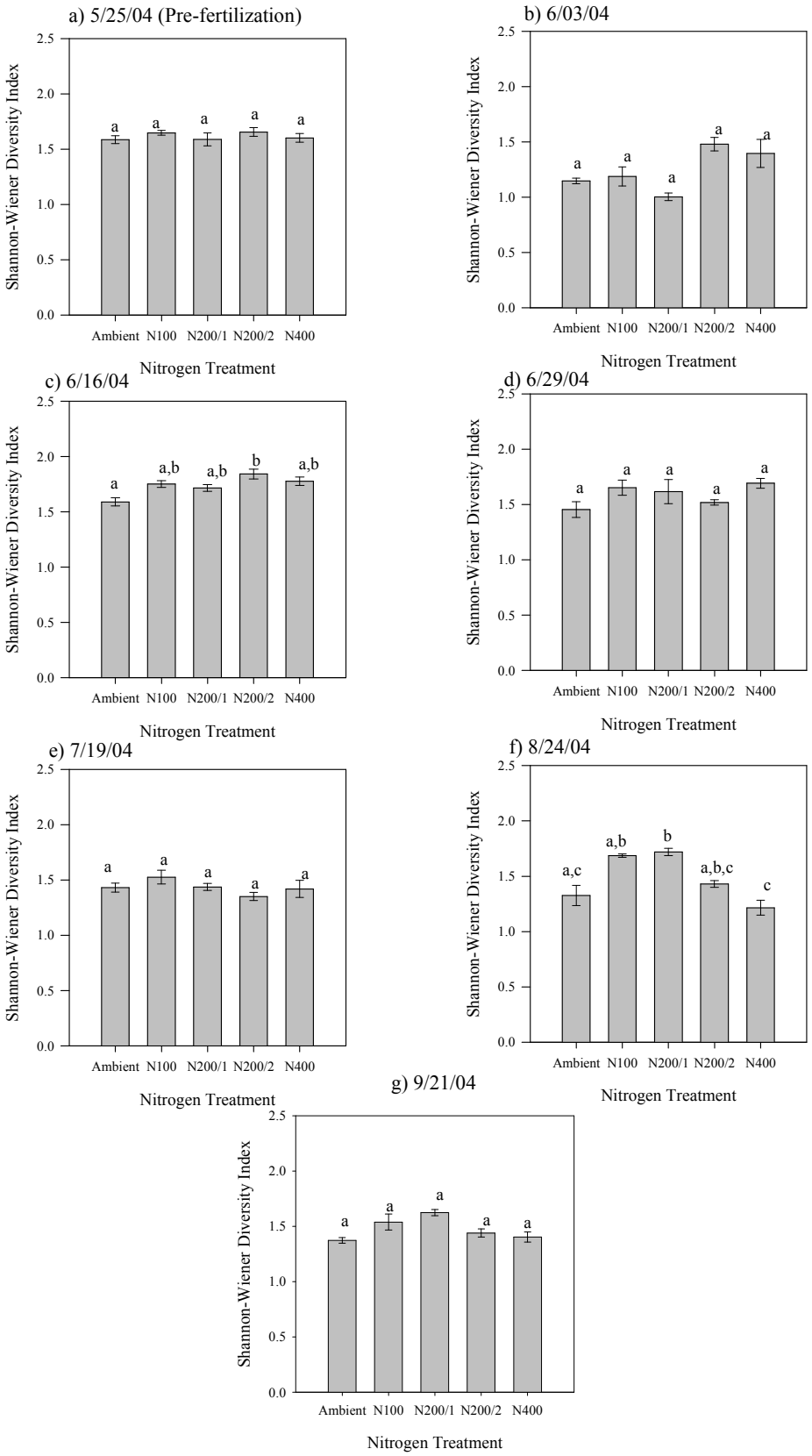
| Site | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| PD site | Trt | 0.28 | 4 | 0.07 | 0.88 | 0.509 |
| | Time | 2.22 | 6 | 0.37 | 9.27 | 0.000*** |
| | Time * Trt | 1.16 | 24 | 0.05 | 1.21 | 0.269 |
| | Error | 2.39 | 60 | 0.04 | | |
| PA site | Trt | 1.40 | 4 | 0.35 | 1.60 | 0.256 |
| | Time | 7.79 | 6 | 1.30 | 14.95 | 0.000*** |
| | Time * Trt | 1.69 | 24 | 0.07 | 0.81 | 0.705 |
| | Error | 4.69 | 54 | 0.09 | | |

**Table 3.2.26 ANOVA model: Site + Trt + (Site*Trt) at all sample dates for the Shannon-Wiener diversity index. *** <0.01, ** < 0.05, * < 0.10**

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 5/25/2004 | Site | 0.73 | 1 | 0.73 | 21.61 | 0.000*** |
| | Trt | 0.30 | 4 | 0.07 | 2.21 | 0.105 |
| | Site * Trt | 0.25 | 4 | 0.06 | 1.83 | 0.162 |
| | Error | 0.67 | 20 | 0.03 | | |
| 6/3/2004 | Site | 0.19 | 1 | 0.19 | 2.16 | 0.158 |
| | Trt | 0.83 | 4 | 0.21 | 2.30 | 0.096* |
| | Site * Trt | 0.29 | 4 | 0.07 | 0.79 | 0.543 |
| | Error | 1.71 | 19 | 0.09 | | |
| 6/16/2004 | Site | 0.43 | 1 | 0.43 | 20.20 | 0.000*** |
| | Trt | 0.22 | 4 | 0.06 | 2.63 | 0.065* |
| | Site * Trt | 0.05 | 4 | 0.01 | 0.64 | 0.640 |
| | Error | 0.42 | 20 | 0.02 | | |

| Date | Source | Type III SS | df | MS | F | Sig |
|---|---|---|---|---|---|---|
| 6/29/2004 | Site | 0.20 | 1 | 0.20 | 2.83 | 0.108 |
| | Trt | 0.22 | 4 | 0.05 | 0.77 | 0.556 |
| | Site * Trt | 0.33 | 4 | 0.08 | 1.17 | 0.352 |
| | Error | 1.42 | 20 | 0.07 | | |
| 7/19/2004 | Site | 1.58 | 1 | 1.58 | 18.44 | 0.000*** |
| | Trt | 0.21 | 4 | 0.05 | 0.60 | 0.666 |
| | Site * Trt | 0.56 | 4 | 0.14 | 1.64 | 0.203 |
| | Error | 1.71 | 20 | 0.09 | | |
| 8/24/2004 | Site | 5.32 | 1 | 5.32 | 49.48 | 0.000*** |
| | Trt | 0.18 | 4 | 0.05 | 0.43 | 0.786 |
| | Site * Trt | 0.82 | 4 | 0.20 | 1.90 | 0.149 |
| | Error | 2.15 | 20 | 0.11 | | |
| 9/21/2004 | Site | 3.05 | 1 | 3.05 | 24.27 | 0.000*** |
| | Trt | 0.25 | 4 | 0.06 | 0.49 | 0.741 |
| | Site * Trt | 0.69 | 4 | 0.17 | 1.38 | 0.277 |
| | Error | 2.51 | 20 | 0.13 | | |
| 6/6/2005 | Site | 0.91 | 1 | 0.91 | 27.38 | 0.000 |
| | Trt | 0.18 | 4 | 0.05 | 1.37 | 0.278 |
| | Site * Trt | 0.51 | 4 | 0.13 | 3.87 | 0.017** |
| | Error | 0.66 | 20 | 0.03 | | |
| 8/2/2005 | Site | 0.18 | 1 | 0.18 | 1.92 | 0.181 |
| | Trt | 0.37 | 4 | 0.09 | 0.99 | 0.437 |
| | Site * Trt | 0.38 | 4 | 0.09 | 1.00 | 0.431 |
| | Error | 1.88 | 20 | 0.09 | | |

Analysis of nitrogen effects on the Shannon-Wiener diversity index for individual dates at the *Phragmites*-dominant site found no nitrogen effects, except in late-August (8/24/04) when a high addition of nitrogen had a low diversity index and mid-fertilization had a very high diversity index (Figure 3.2.29f).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Shannon-Wiener Diversity Index
Nitrogen Treatment
Ambient
N100
N200/1
N200/2
N400
0.0
0.5
1.0
1.5
2.0
2.5
a
a,b
a,c
b
c

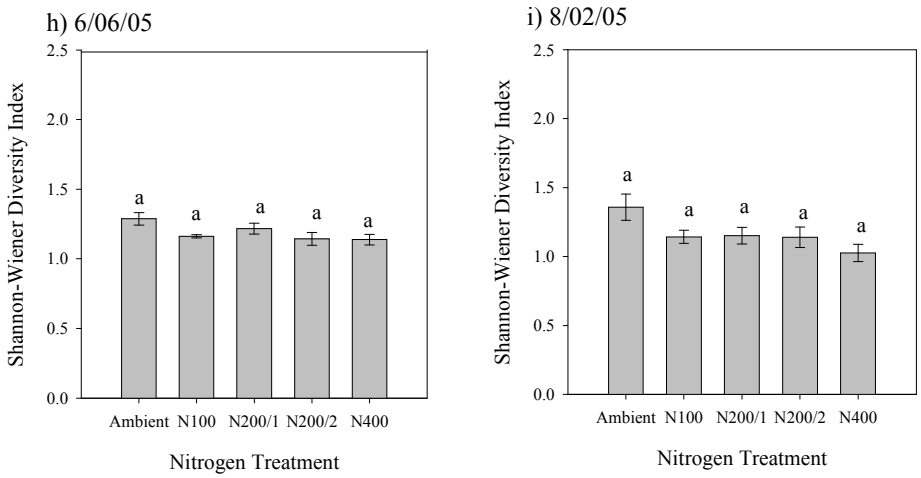
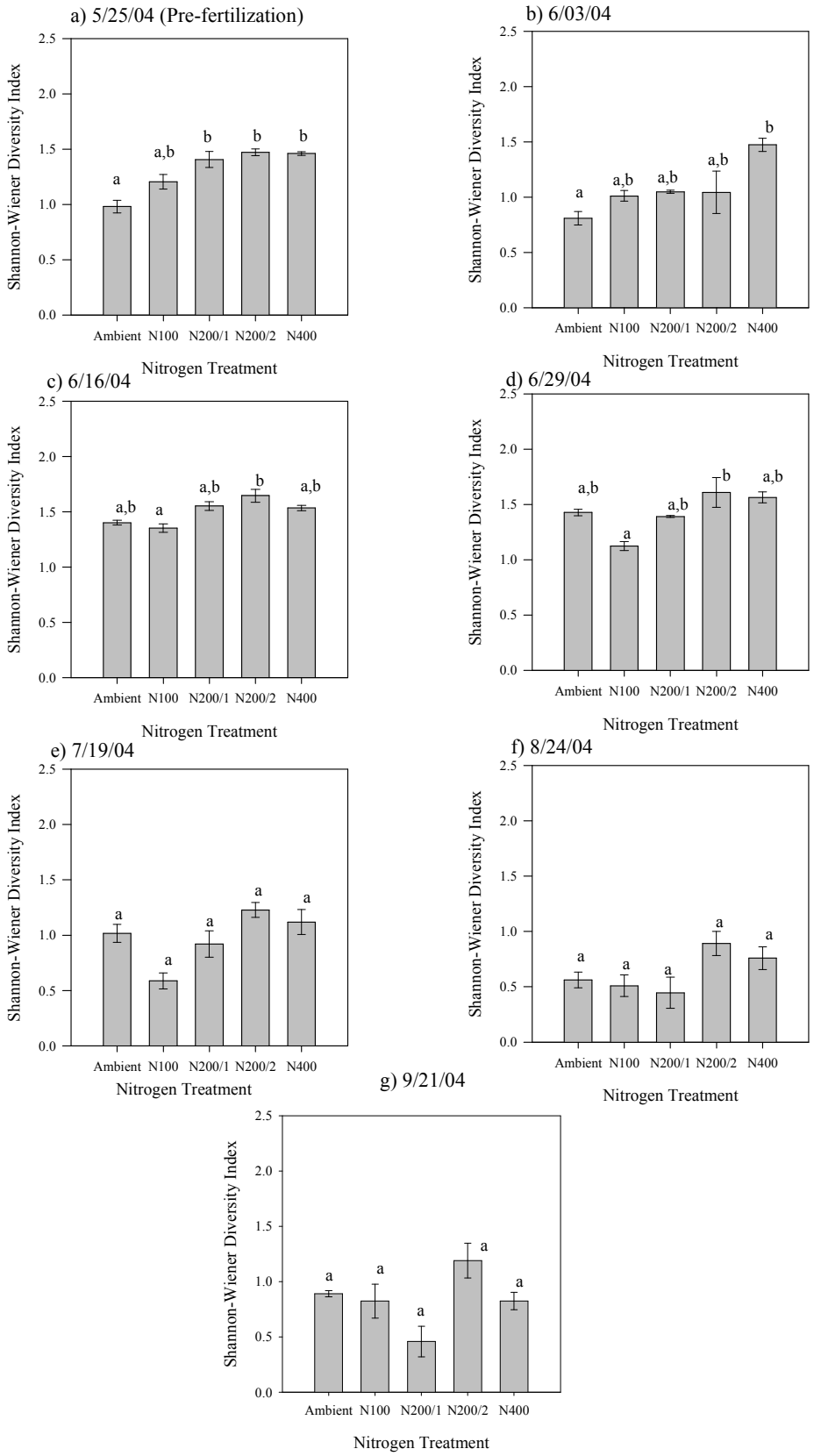



**Figure 3.2.29. Mean diversity index and standard errors at the *Phragmites*-dominant site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Diversity index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

Detection of a nitrogen effect on Shannon-Wiener diversity index at the *Phragmites*-absent site was confounded by the fact that the pre-fertilization date was correlated to nitrogen treatment (Figure 3.2.30).


a) 5/25/04 (Pre-fertilization)
b) 6/03/04
c) 6/16/04
d) 6/29/04
e) 7/19/04
f) 8/24/04
g) 9/21/04
Shannon-Wiener Diversity Index
Nitrogen Treatment
Ambient
N100
N200/1
N200/2
N400

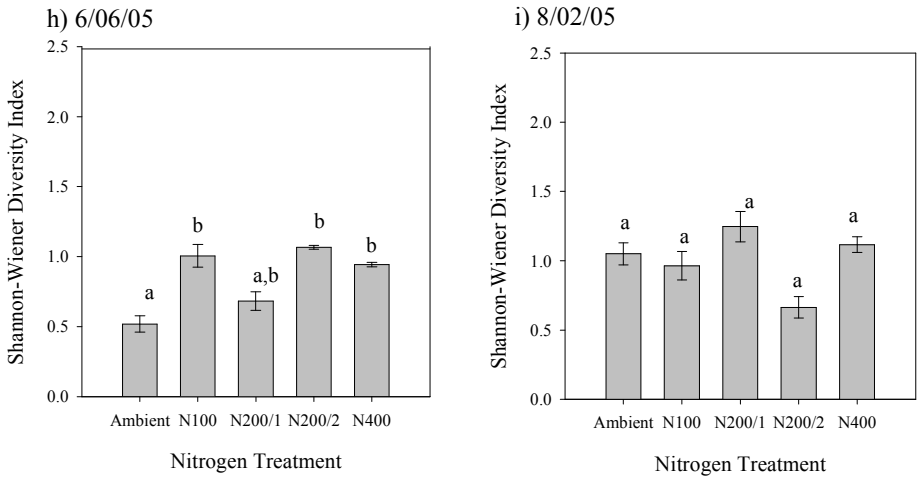



**Figure 3.2.30. Mean diversity index and standard errors at the *Phragmites*-absent site according to nitrogen treatment over the 2004-5 growing seasons. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Diversity index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*Effects on Biomass*

Plots given more urea had higher biomass at the *Phragmites*-absent site (Figure 3.2.31), but there was no difference among plots at the *Phragmites*-dominant site (Figure 3.2.32). *P. arifolium* and *I. capensis* dominated the *Phragmites*-absent site in August (Figure 3.2.2c), and both had a high cover at high levels of nitrogen fertilization, possibly contributing to the high biomass at high fertilization levels. Conversely, the *Phragmites*-dominant site was dominated by *P. arifolium*, *I. capensis, and P. australis* in August (Figure 3.2.1c). While *P. arifolium* and *I. capensis* cover had high cover at high levels of fertilization, *P. australis* had a low cover at high levels of fertilization. The differences in nitrogen effects on the dominant species at the *Phragmites*-dominant site may have influenced the biomass at that site. It's also notable that mean biomass at the *Phragmites*-dominant control plots was nearly five times the amount at the *Phragmites*-absent site. Also, the addition of N200/2D as urea doubled the biomass at the *Phragmites*-absent site.

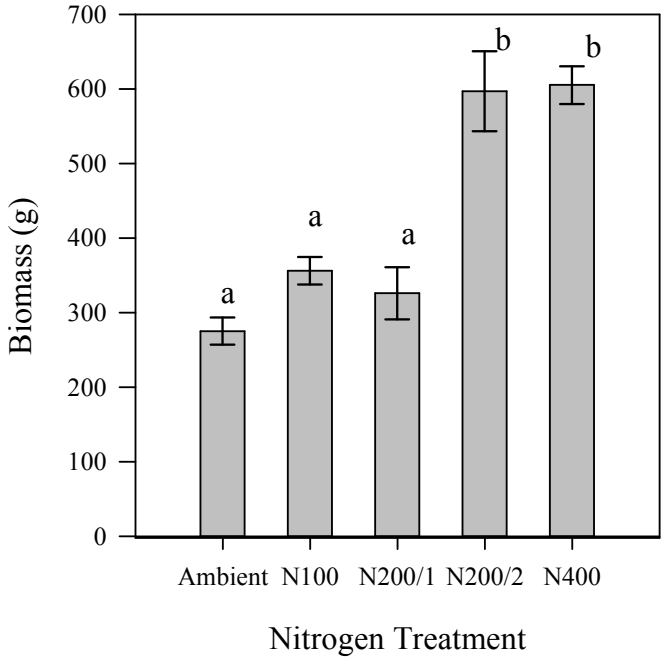



**Figure 3.2.31. Mean biomass and standard errors at the *Phragmites*-absent site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments ($p<0.05$).**

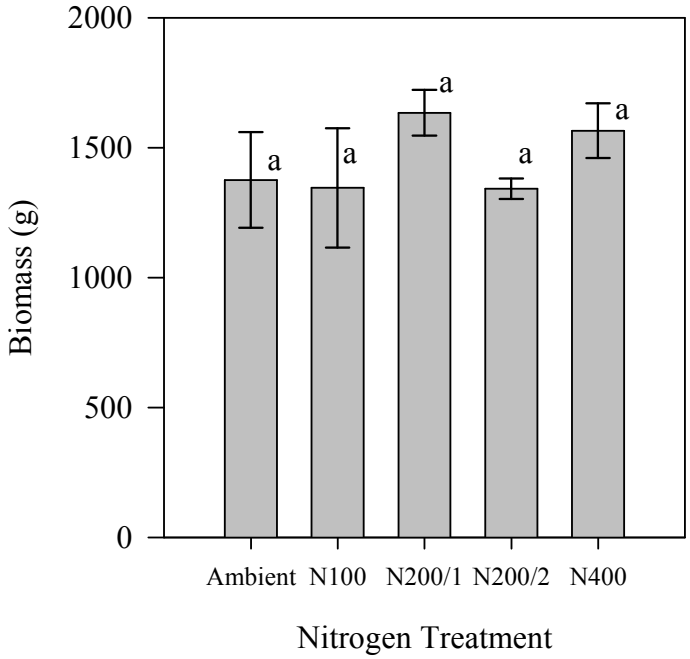



**Figure 3.2.32. Mean biomass and standard errors at the *Phragmites*-dominant site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments ($p<0.05$).**

LAI was positively related to plot biomass (Fig. 3.2.33). However, neither species richness, nor Shannon diversity were related to biomass (Figure 3.2.34 and 3.2.35).

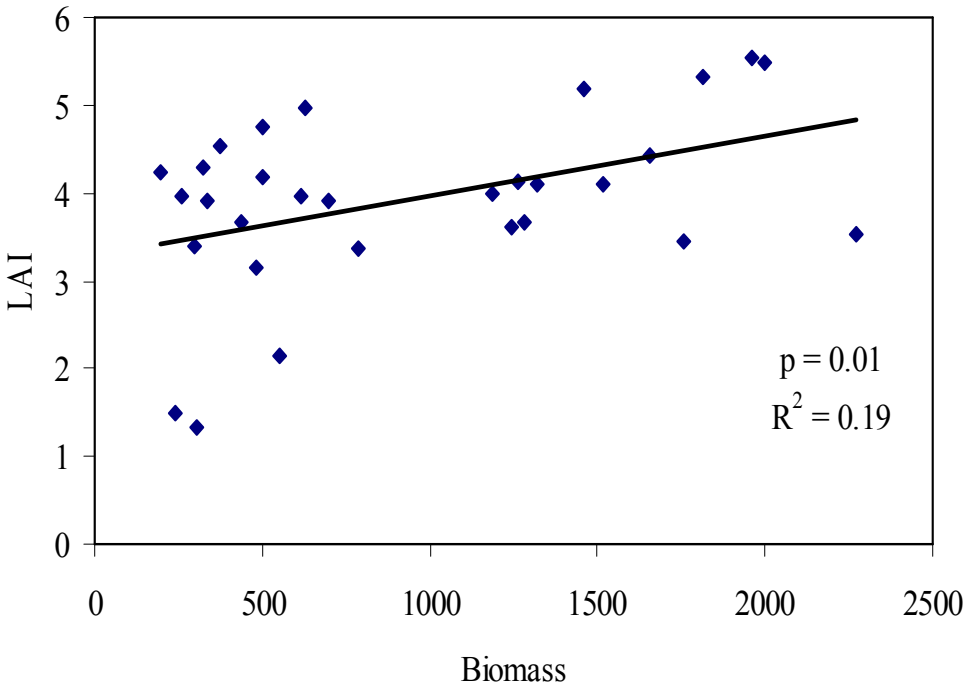



**Figure 3.2.33. Biomass and LAI linear regression for all plots (n = 30) on 8/02/05.**

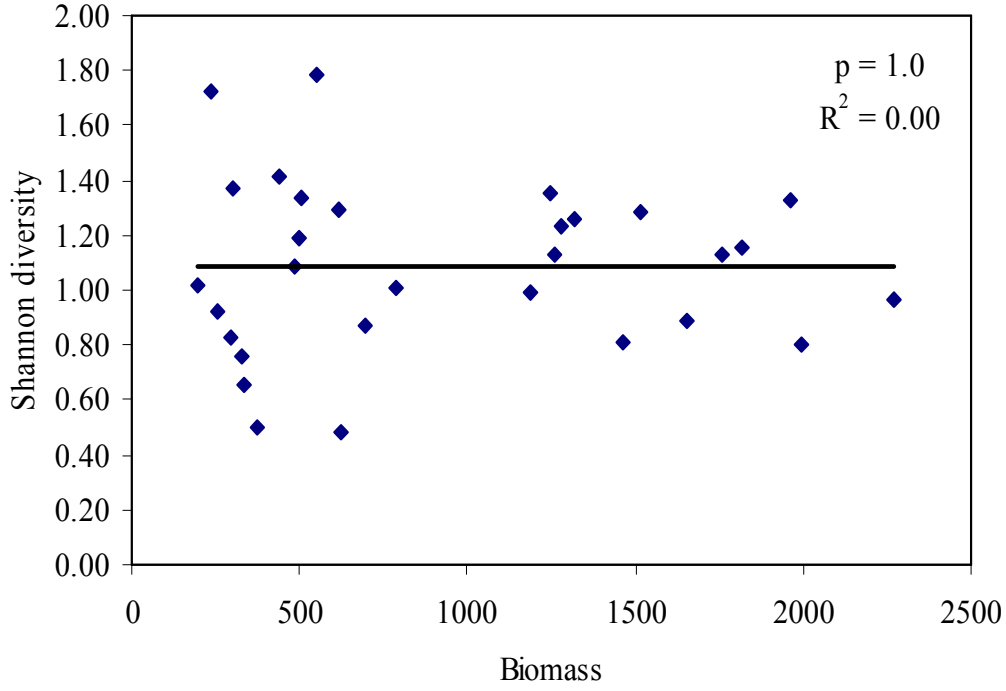



**Figure 3.2.34. Biomass and Shannon diversity index linear regression for all plots (n = 30) on 8/02/05.**

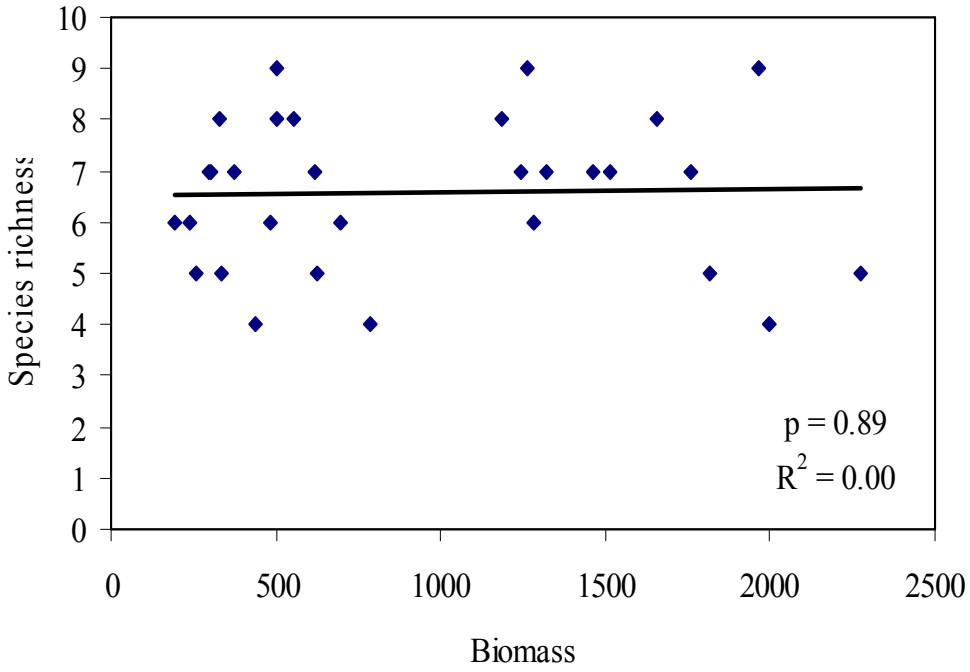



**Figure 3.2.35. Biomass and species richness linear regression for all plots (n = 30) on 8/02/05.**

*3.2.3 Nitrogen fertilization effects on canopy nutrients*

The addition of nitrogen increased canopy nitrogen at the *Phragmites*-absent site (Figure 3.2.36), but did not conclusively increase vegetation nitrogen concentration at the *Phragmites*-dominant site (Figure 3.2.37). Nitrogen fertilization also increased canopy phosphorus at the *Phragmites*-absent site (Figure 3.2.38), but did not alter phosphorus at the *Phragmites*-dominant site (Figure 3.2.39).

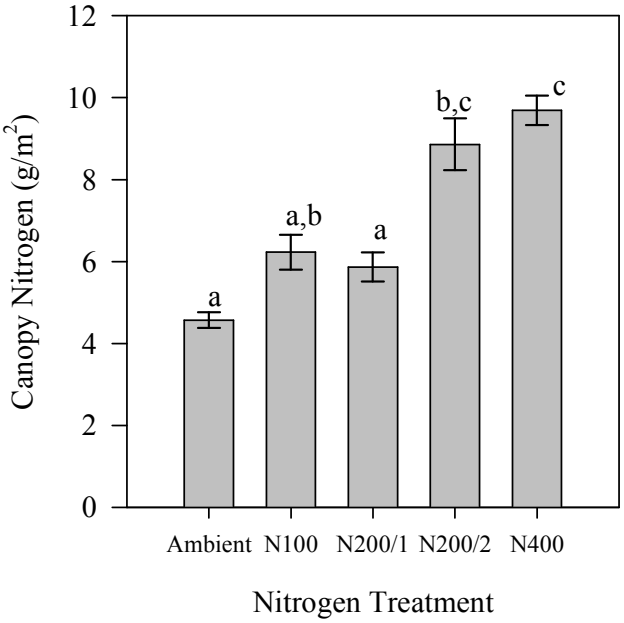



**Figure 3.2.36. Mean canopy nitrogen and standard errors at the *Phragmites*-absent site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments ($p<0.05$).**

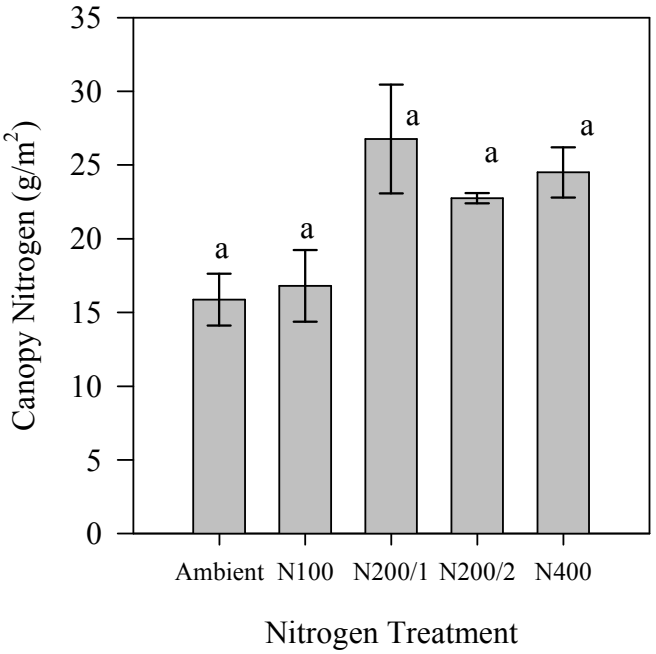



**Figure 3.2.37. Mean canopy nitrogen and standard errors at the *Phragmites*-dominant site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments ($p<0.05$).**

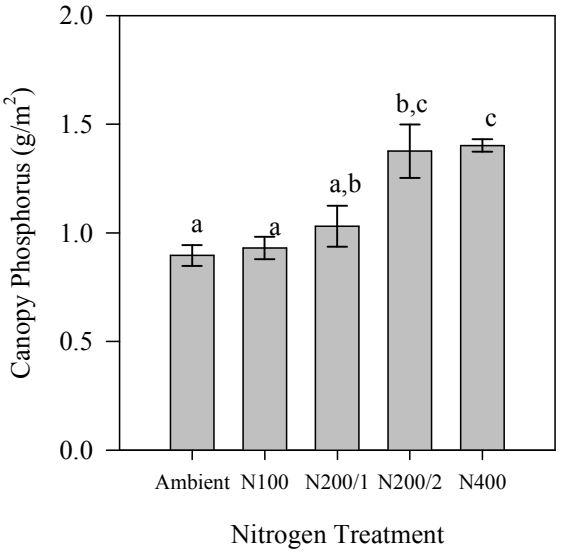



**Figure 3.2.38. Mean canopy phosphorus and standard errors at the *Phragmites*-absent site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments ($p<0.10$).**

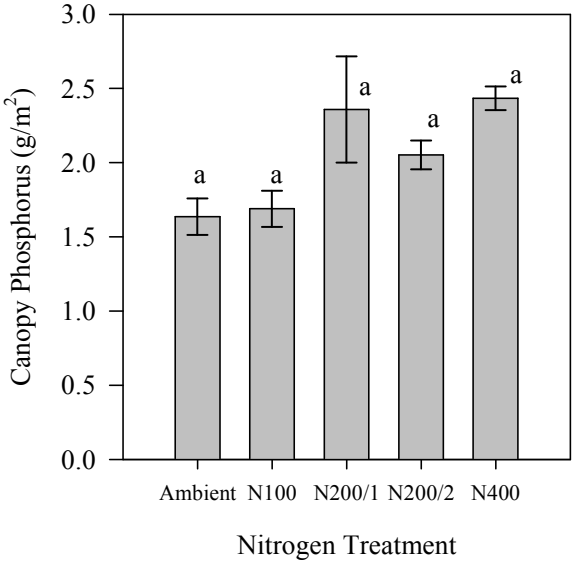



**Figure 3.2.39. Mean canopy phosphorus and standard errors at the *Phragmites*-dominant site according to nitrogen treatment on 8/02/05. Treatments with different letters indicate a significant difference between treatments (p<0.10).**

The mean canopy nitrogen and phosphorus for each of the top six species is shown according to nitrogen treatment (Tables 3.2.27 and 3.2.28). *A. calamus* and *Typha* species both had high canopy nitrogen and phosphorus with a large addition of urea, whereas *I. capensis* and *P. arifolium* had high canopy nitrogen and phosphorus with low fertilization and high fertilization (Tables 3.2.27 and 3.2.28). *P. virginica* had high canopy nitrogen and phosphorus with medium fertilization (Tables 3.2.27 and 3.2.28).

**Table 3.2.27. Mean canopy nitrogen (g/m$^2$) for the top six species according to nitrogen treatment on 8/02/05.**

| Species | N0 (control) | N100 | N200/1D | N200/2D | N400 |
|---|---|---|---|---|---|
| *A. calamus* | 1.22 | 1.68 | 1.68 | 1.49 | 2.04 |
| *I. capensis* | 0.96 | 1.15 | 0.64 | 0.77 | 2.62 |
| *P. virginica* | 1.45 | 1.75 | 2.49 | 1.53 | 1.41 |
| *P. australis* | 11.94 | 12.59 | 21.40 | 17.87 | 18.16 |
| *P. arifolium* | 1.71 | 2.27 | 1.67 | 3.48 | 2.45 |
| *Typha* sp. | 0.30 | 0.52 | 0.29 | 1.28 | 0.99 |

**Table 3.2.28. Mean canopy phosphorus (g/m$^2$) for the top six species according to nitrogen treatment on 8/02/05.**

| Species | N0 (control) | N100 | N200/1D | N200/2D | N400 |
|---|---|---|---|---|---|
| *A. calamus* | 0.18 | 0.27 | 0.26 | 0.25 | 0.36 |
| *I. capensis* | 0.13 | 0.15 | 0.07 | 0.08 | 0.30 |
| *P. virginica* | 0.31 | 0.30 | 0.45 | 0.27 | 0.23 |
| *P. australis* | 1.03 | 1.04 | 1.62 | 1.34 | 1.52 |
| *P. arifolium* | 0.32 | 0.34 | 0.30 | 0.56 | 0.34 |
| *Typha* sp. | 0.04 | 0.06 | 0.04 | 0.15 | 0.17 |

Patterns in species canopy nutrients for each treatment mimic nitrogen effects on species percent cover, which suggests a correlation between biomass and canopy nutrients. Canopy nitrogen was positively related to biomass (Figure 3.2.40), as was canopy phosphorus (Figure 3.2.41).

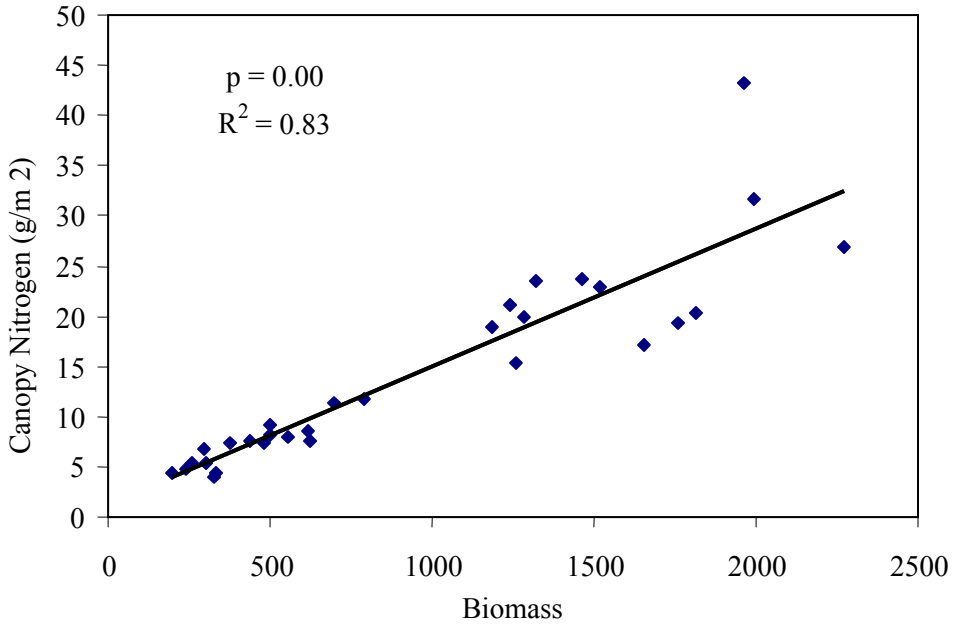



**Figure 3.2.40. Biomass and canopy nitrogen linear regression for all plots (n = 30) on 8/02/05.**

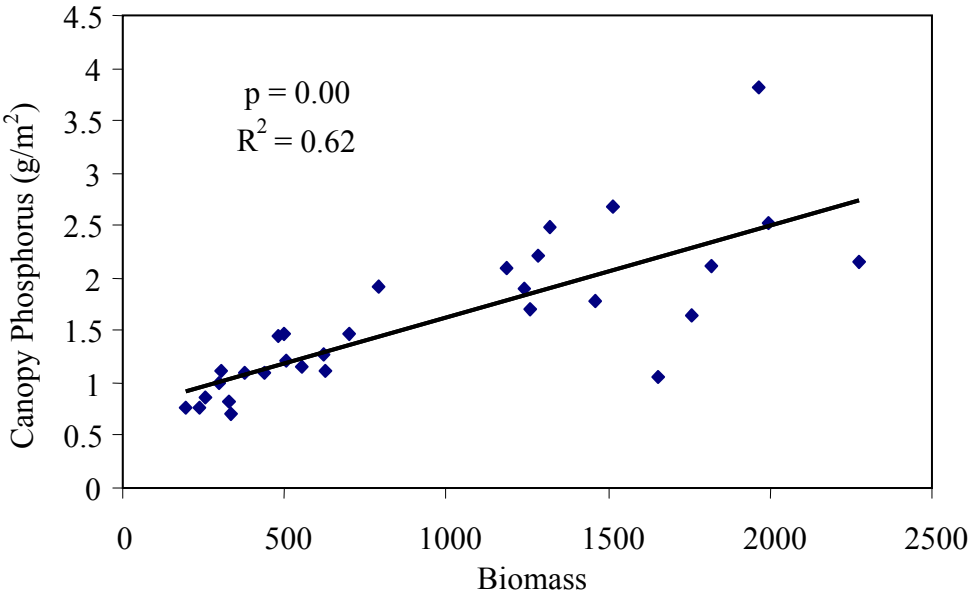



**Figure 3.2.41. Biomass and canopy phosphorus linear regression for all plots (n = 30) on 8/02/05.**

Canopy nitrogen was also positively related to canopy phosphorus (Figure 3.2.42), but not to sub-surface water ammonia (Figure 3.2.43). Likewise, canopy phosphorus was not related to sub-surface total phosphorus (Figure 3.2.44).

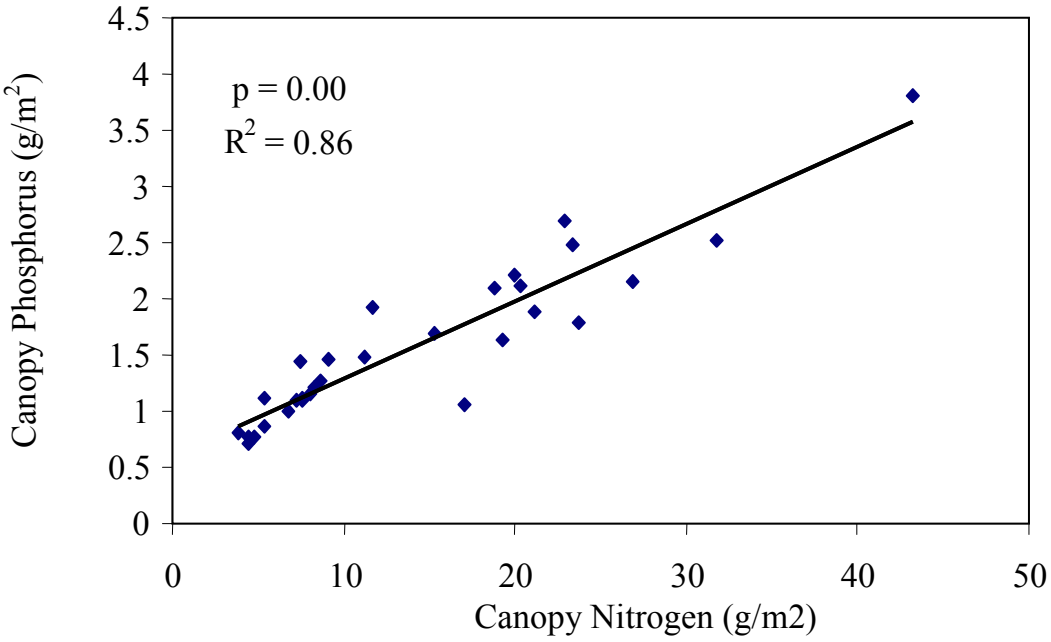



**Figure 3.2.42. Canopy nitrogen and phosphorus linear regression for all plots (n = 30) on 8/02/05.**

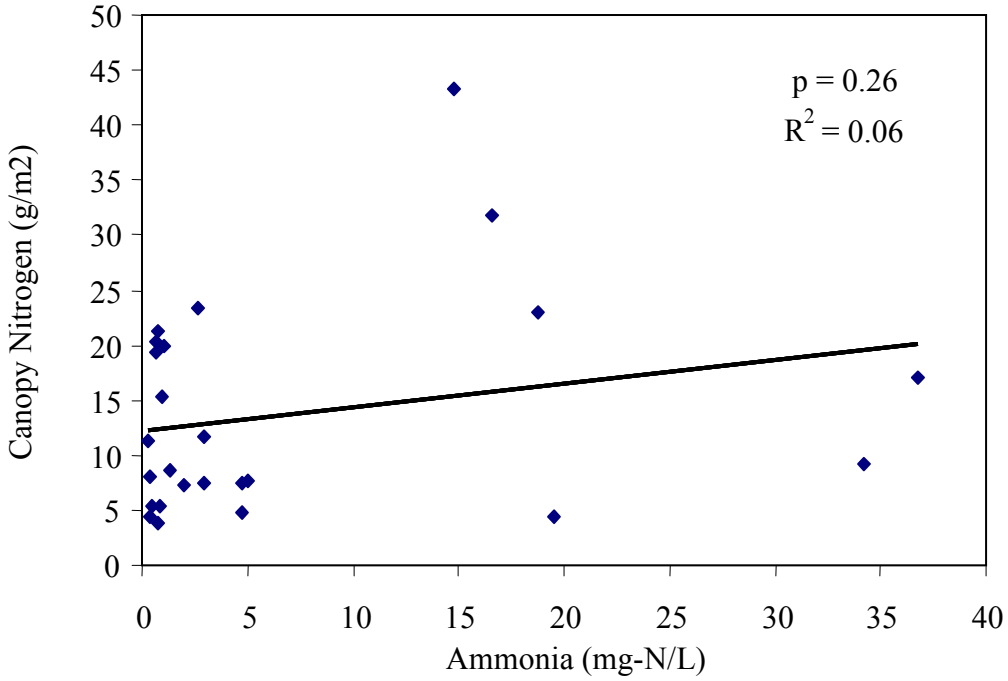



**Figure 3.2.43. Sub-surface water ammonia and canopy nitrogen linear regression for all plots (n = 30) on 8/02/05.**

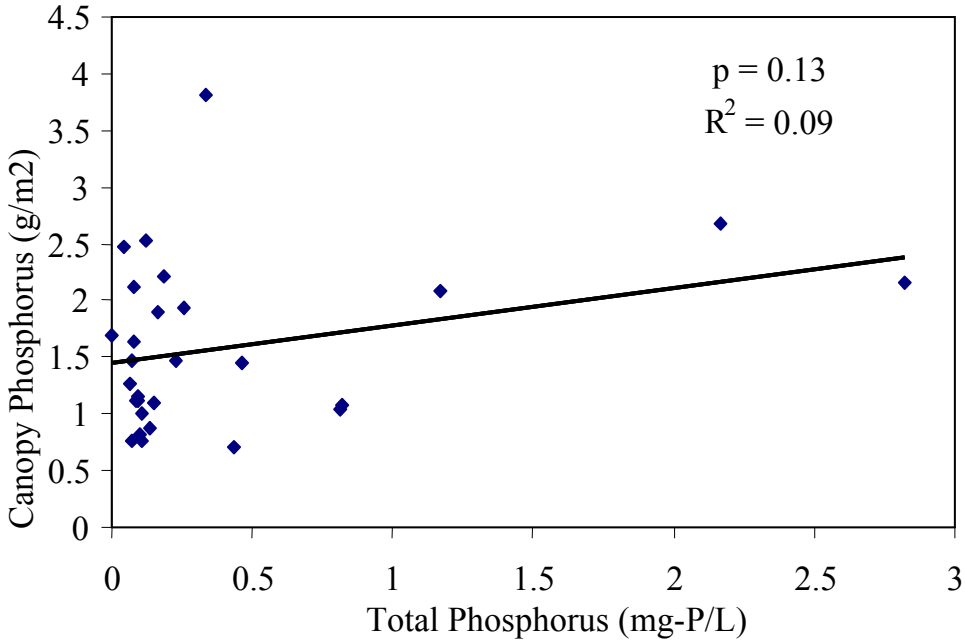



**Figure 3.2.44. Sub-surface water total phosphorus and canopy phosphorus linear regression for all plots (n = 30) on 8/02/05.**

### *3.3 Marsh Canopy Reflectance Response*

Marsh canopy reflectance was analyzed to determine its response to nitrogen fertilization and vegetation composition. Basic trends of the reflectance over the growing season are outlined in the following section, as are ANOVA's to evaluate the effect of time, site and nitrogen on canopy reflectance.

#### *3.3.1 Seasonal dynamics of canopy reflectance*

Since nutrient concentrations and vegetation communities changed over time, canopy reflectance was analyzed to determine its seasonal dynamics. Figure 3.3.1 shows the mean canopy hyperspectral reflectance of six unfertilized plots within the two marsh sites in late May, mid-July, and late-September. As the summer progressed, the marsh canopy reflected less VNIR, except in the visible red waveband, which stayed relatively constant for all three dates.

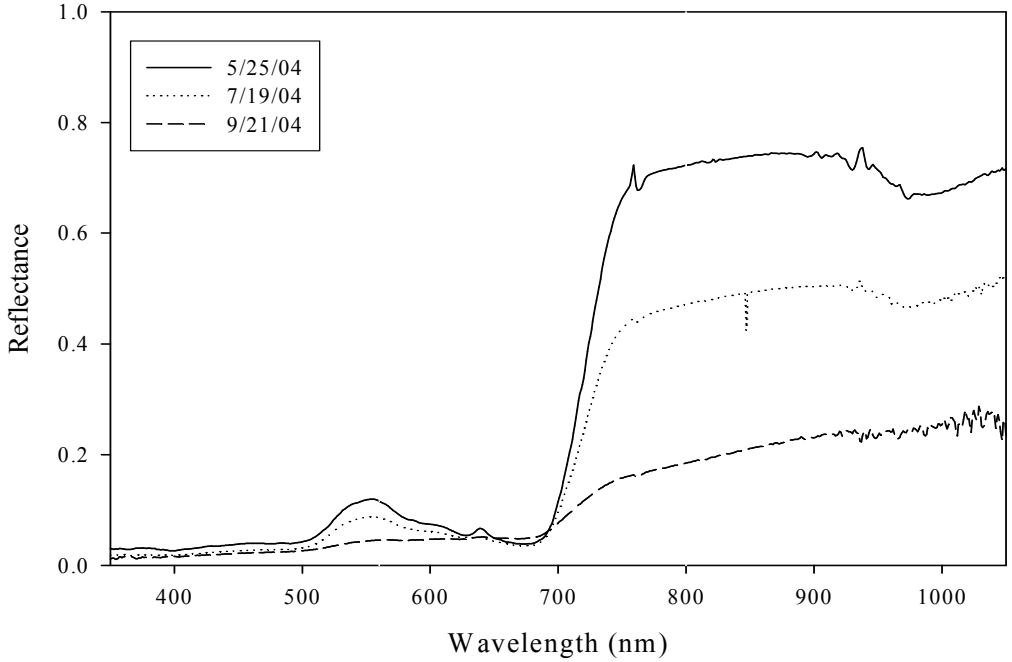



**Figure 3.3.1. Mean hyperspectral reflectance of combined marsh sites in late May, mid-July, and late-September for unfertilized plots.**

A linear regression was performed to quantify the seasonal effects on major multispectral waveband reflectance. Figures 3.3.2 and 3.3.3 illustrate the seasonal changes in the reflectance of the four Landsat TM wavebands (blue 450-520nm; green 520-600nm; red 630-690nm; near-infrared 760-900nm) for the unfertilized plots and the most heavily fertilized plots, respectively. The red waveband did not change in reflectance as the summer progressed for either the unfertilized or the heavily fertilized plots. The blue, green, and near-infrared wavebands declined throughout the summer for both the unfertilized and highly fertilized plots.

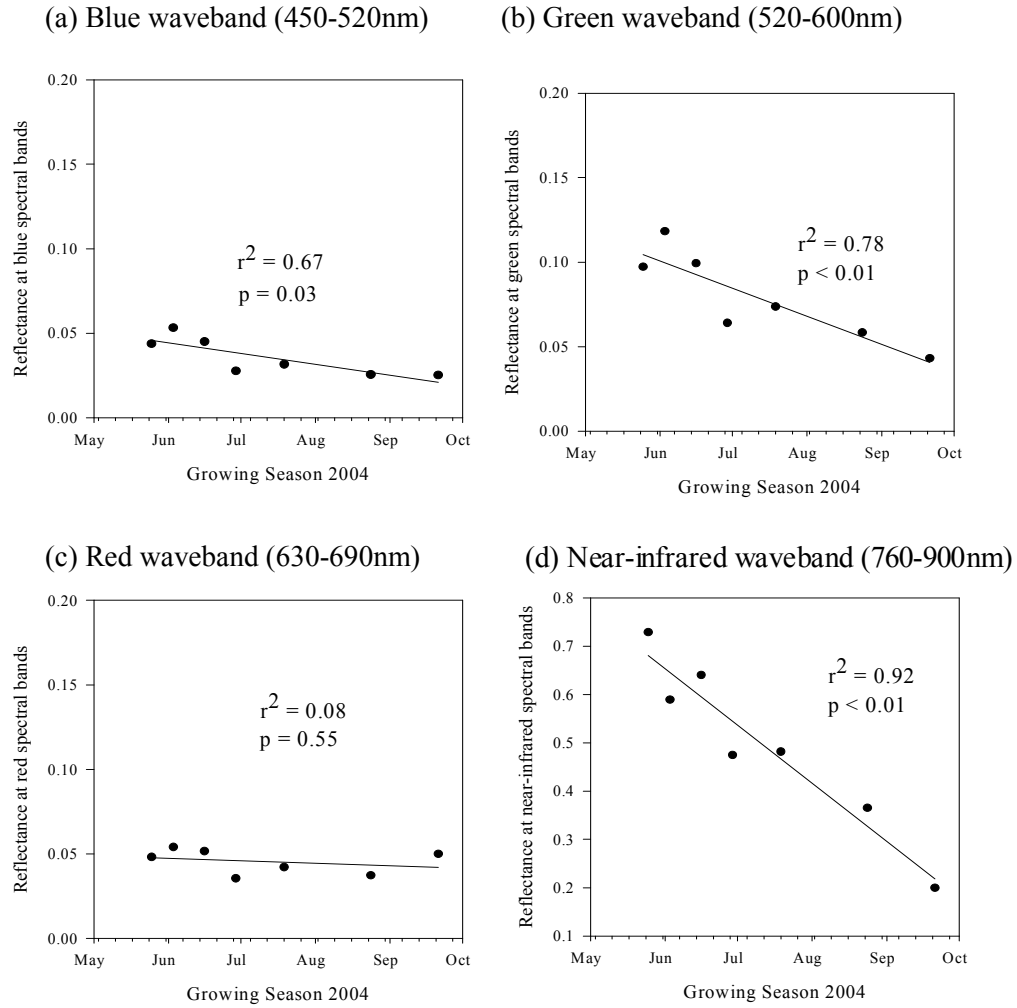



**Figure 3.3.2. Mean reflectance of unfertilized plots (n = 6) for combined marsh sites throughout the 2004 growing season for (a) blue waveband (450-520nm) (b) green waveband (520-600nm), (c) red waveband (630-690nm), and (d) near-infrared waveband (760-900nm).**

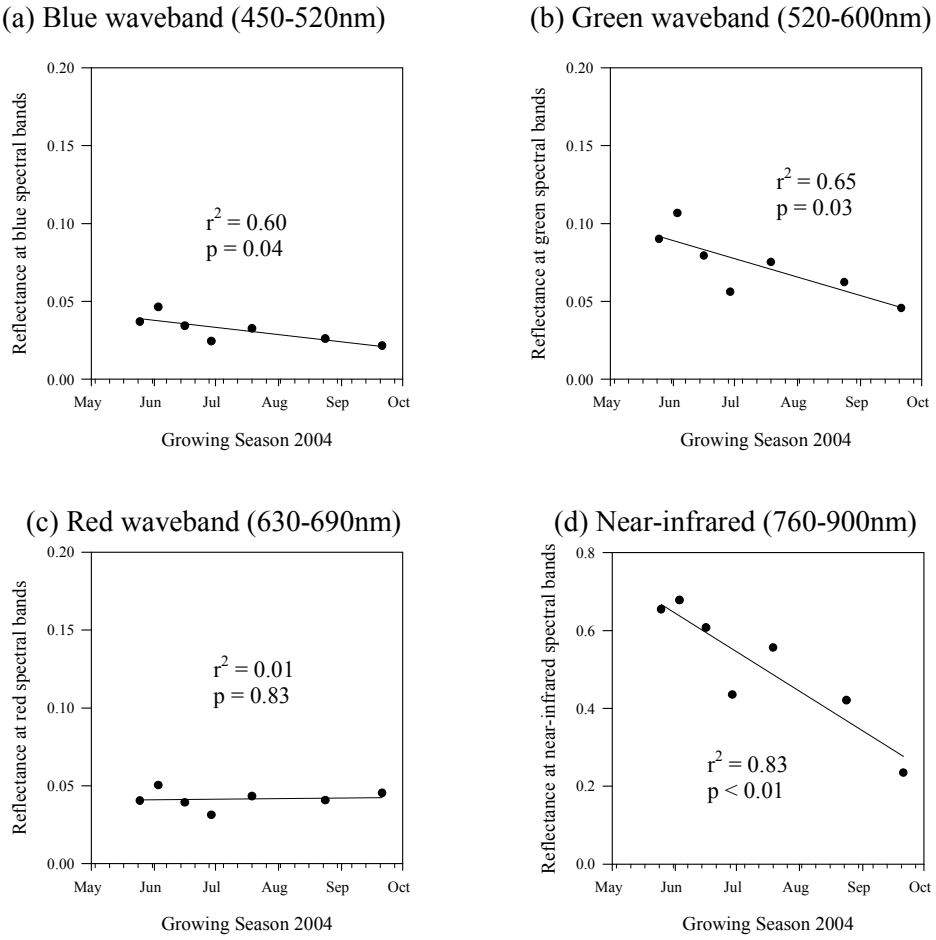



**Figure 3.3.3. Mean reflectance of highly fertilized plots (n = 6) for combined marsh sites throughout the 2004 growing season for (a) blue waveband (450-520nm) (b) green waveband (520-600nm), (c) red waveband (630-690nm), and (d) near-infrared waveband (760-900nm).**

### *3.3.2 Detection of nitrogen effect on reflectance indices*

Three simple ratios, $R_{493}/R_{678}$, $R_{415}/R_{710}$ and $R_{564}/R_{768}$, and two reflectance indices, PRI and NDVI, were analyzed for their response to nitrogen. A one-way ANOVA model with an LSD contrast was performed for the ratios and indices at each site on every sample date.

#### *$R_{493}/R_{678}$*

The simple ratio $R_{493}/R_{678}$ did not distinguish between the different nitrogen treatments for the *Phragmites*-dominant site (Figure 3.3.4), however the ratio was

higher at the end of the growing season (9/21/04) for the higher nitrogen treatment at the *Phragmites*-absent site (Figure 3.3.5).

*$R_{415}/R_{710}$*

Figures 3.3.6 and 3.3.7 show differences among treatments for the simple ratio $R_{415}/R_{710}$ for the *Phragmites*-dominant and *Phragmites*-absent site, respectively. Similar to the $R_{493}/R_{678}$ ratio, the $R_{415}/R_{710}$ ratio was not generally different during peak growing season, but rather was different at the end in September, but only for the *Phragmites*-dominant site (Figure 3.3.6).

*$R_{564}/R_{768}$*

The simple ratio $R_{564}/R_{768}$ could only differentiate between nitrogen treatments at the end of the growing season for the *Phragmites*-dominant site (Figure 3.3.8), which was similar to the $R_{415}/R_{710}$ ratio.

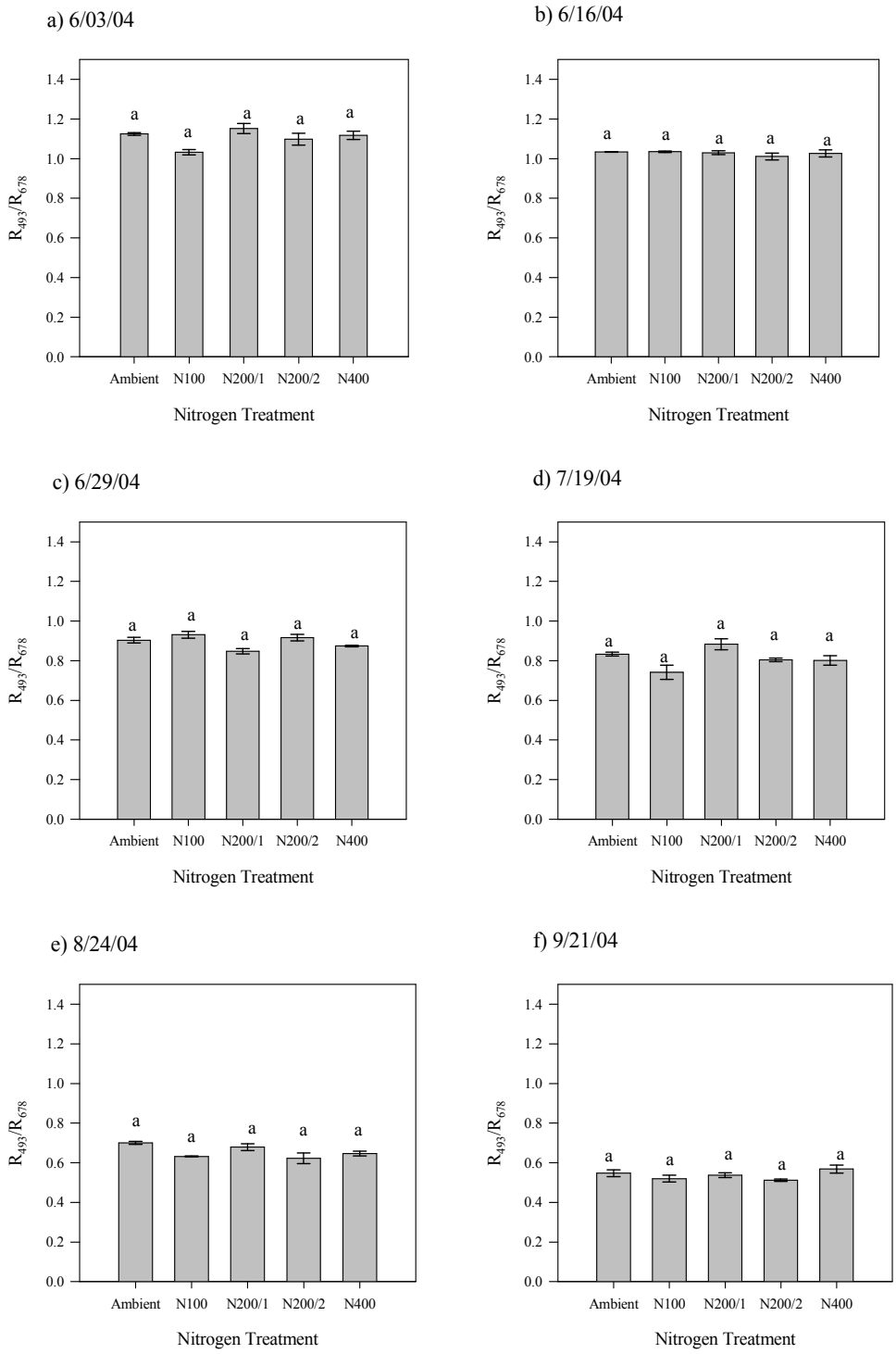



**Figure 3.3.4. Mean $R_{493}/R_{678}$ values and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{493}/R_{678}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

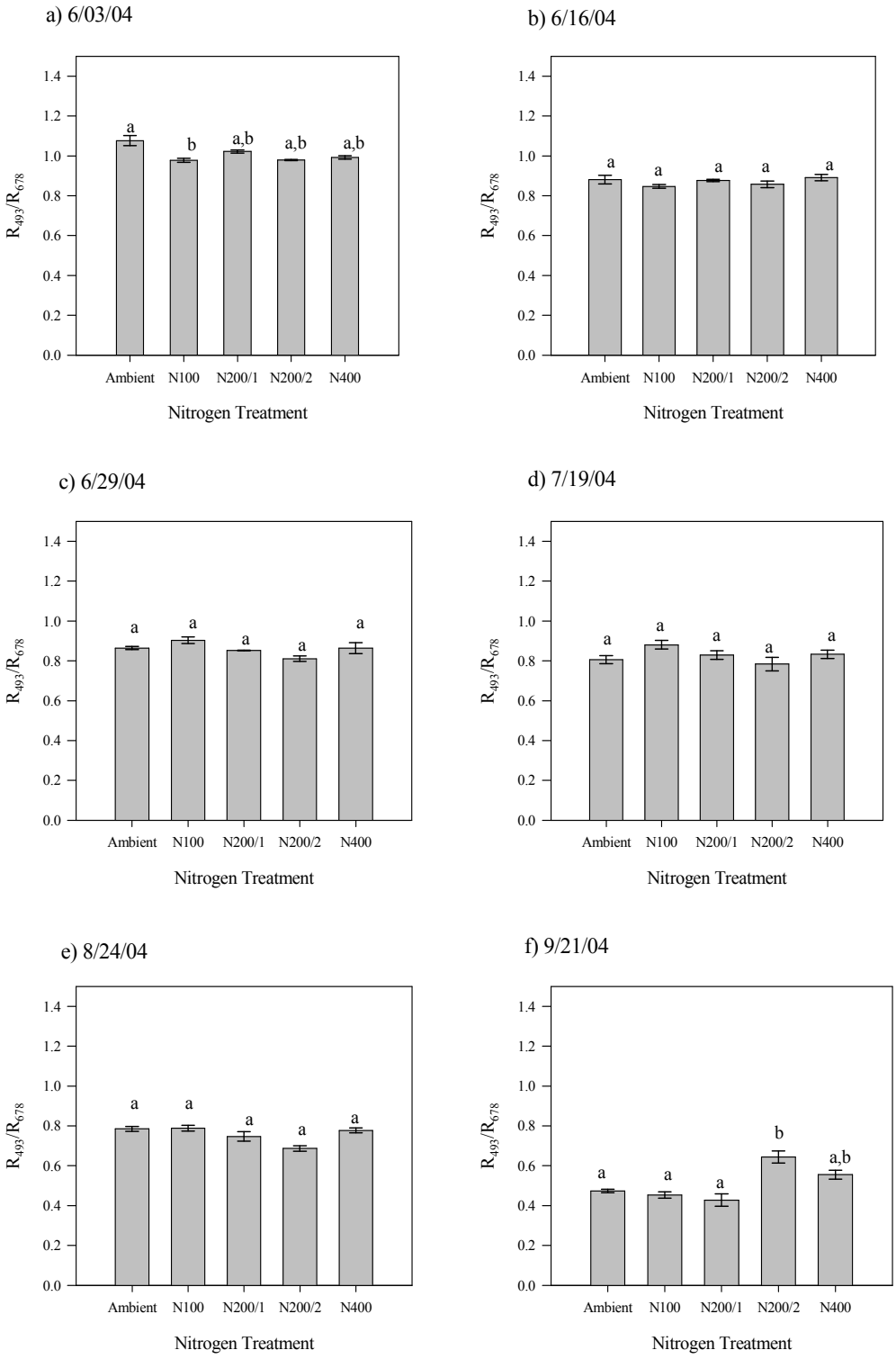



**Figure 3.3.5. Mean $R_{493}/R_{678}$ values and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{493}/R_{678}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

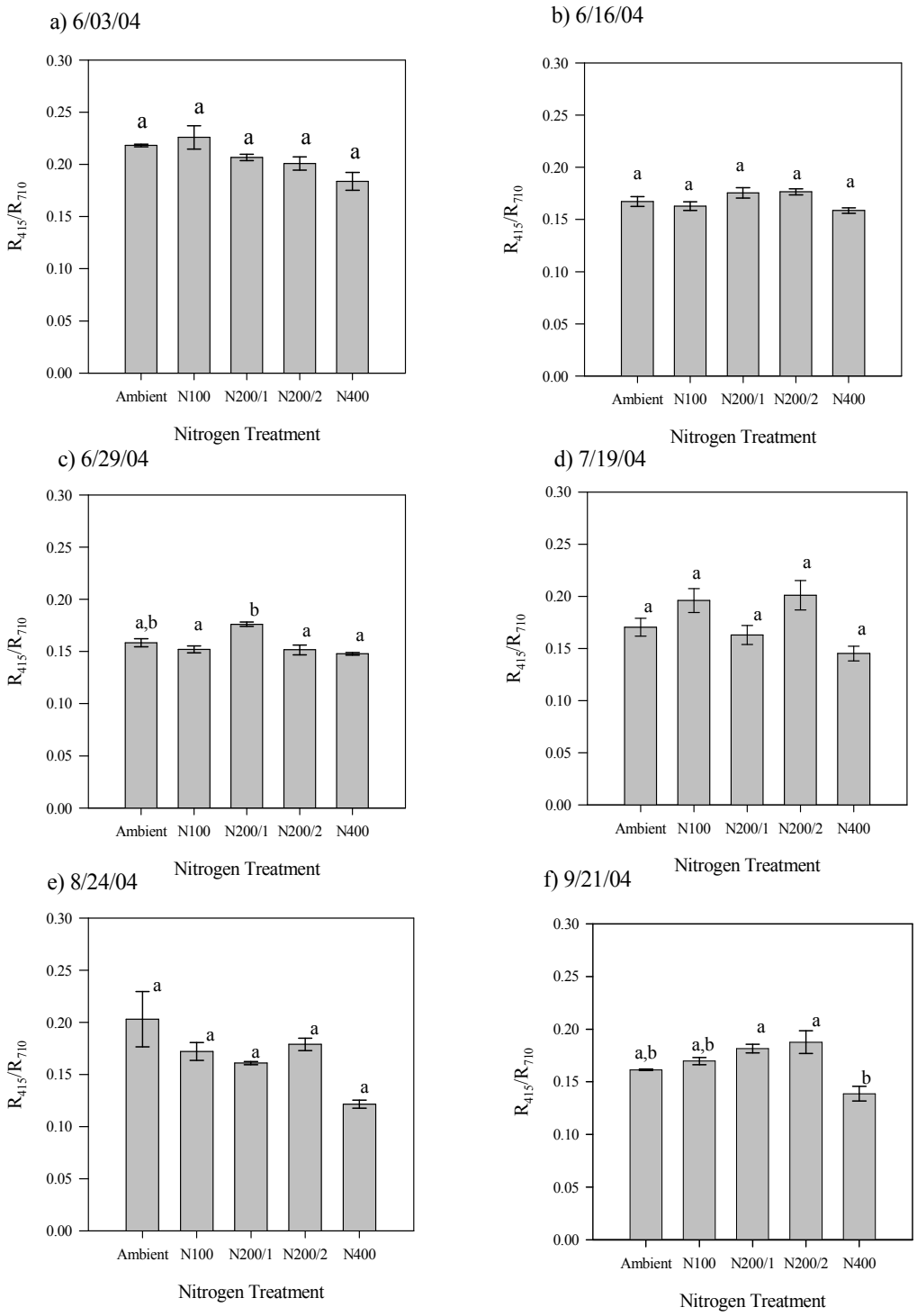



**Figure 3.3.6. Mean $R_{415}/R_{710}$ values and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{415}/R_{710}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

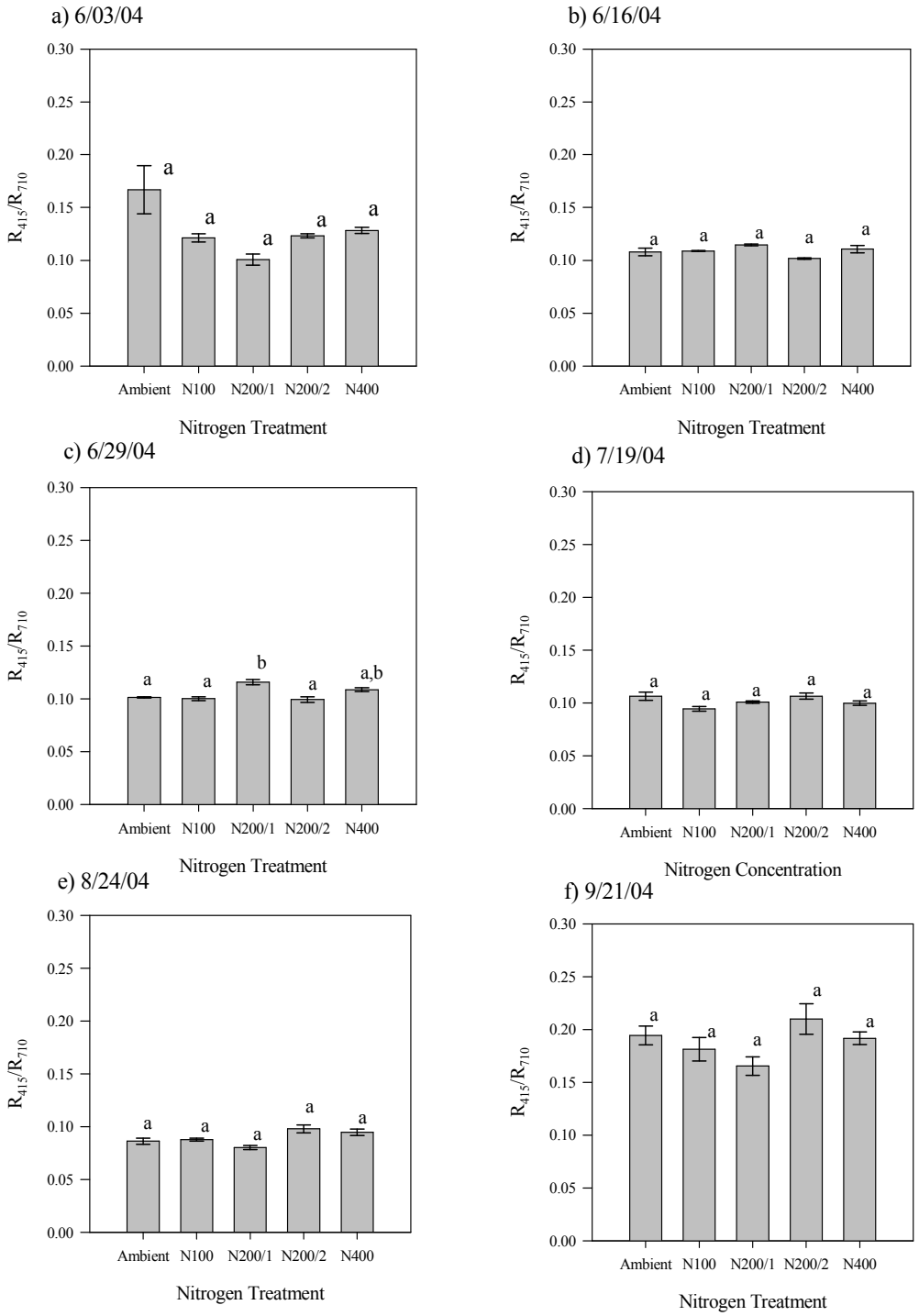



**Figure 3.3.7. Mean $R_{415}/R_{710}$ values and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{415}/R_{710}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

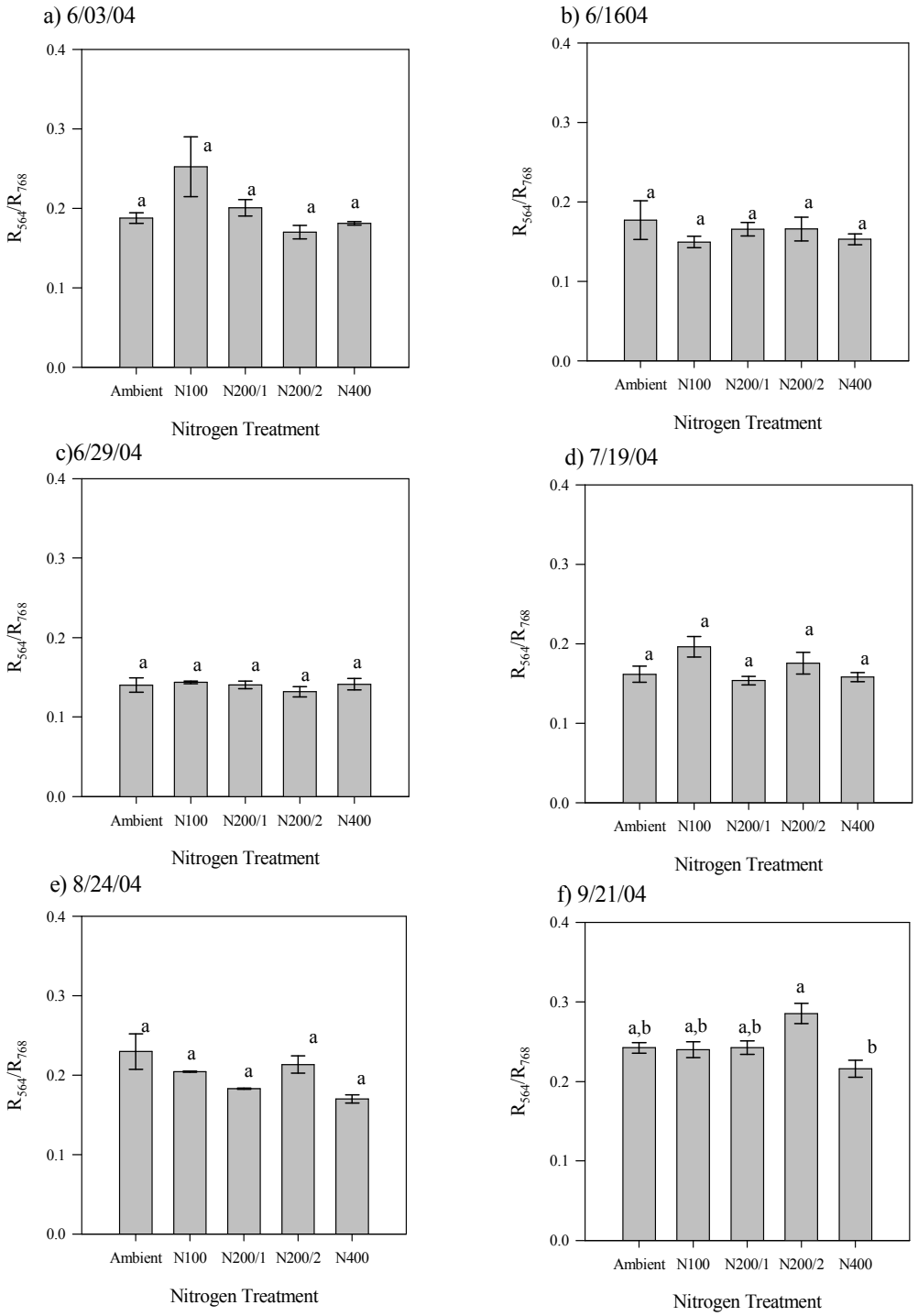



**Figure 3.3.8. Mean $R_{564}/R_{768}$ values and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{564}/R_{768}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

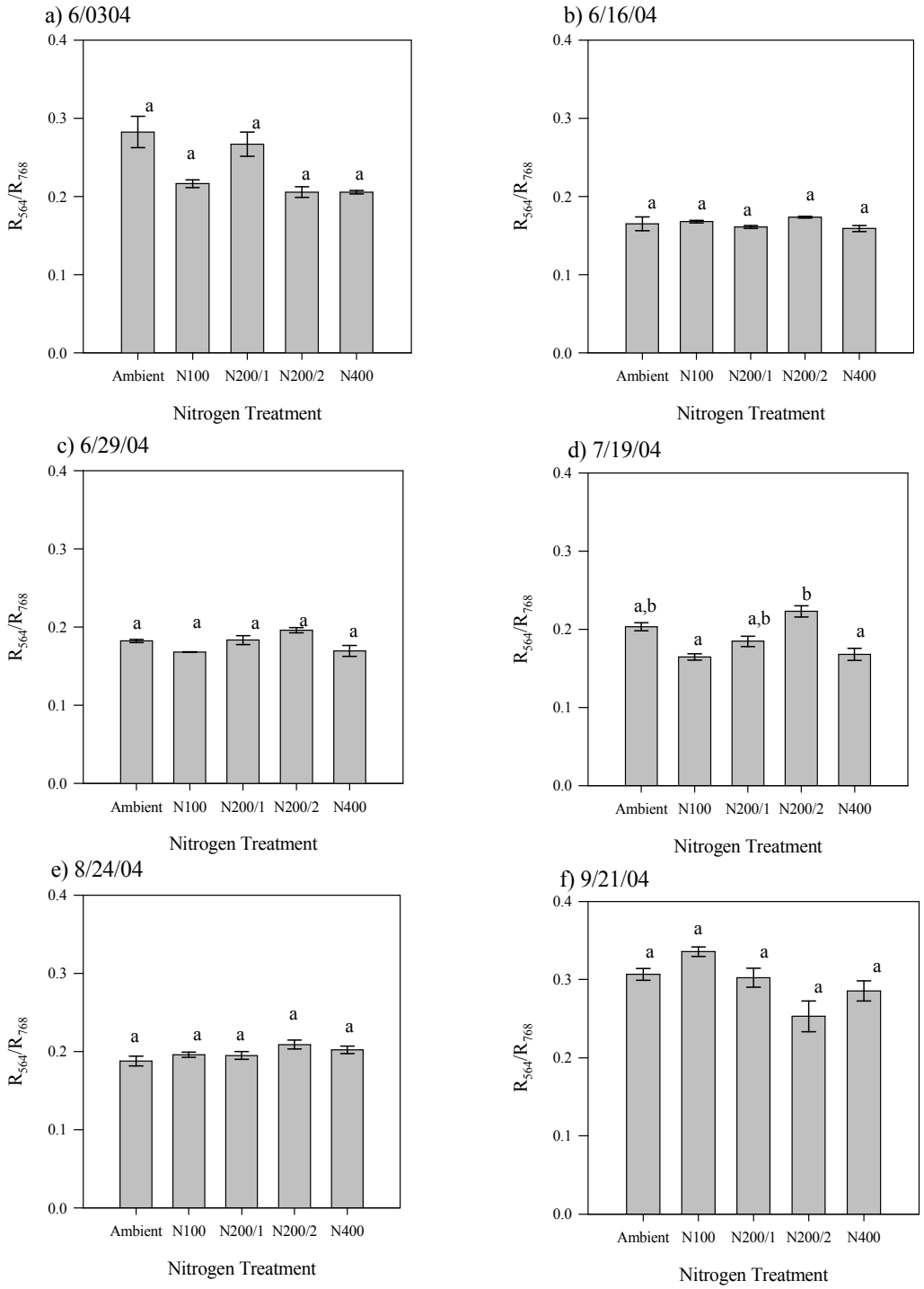


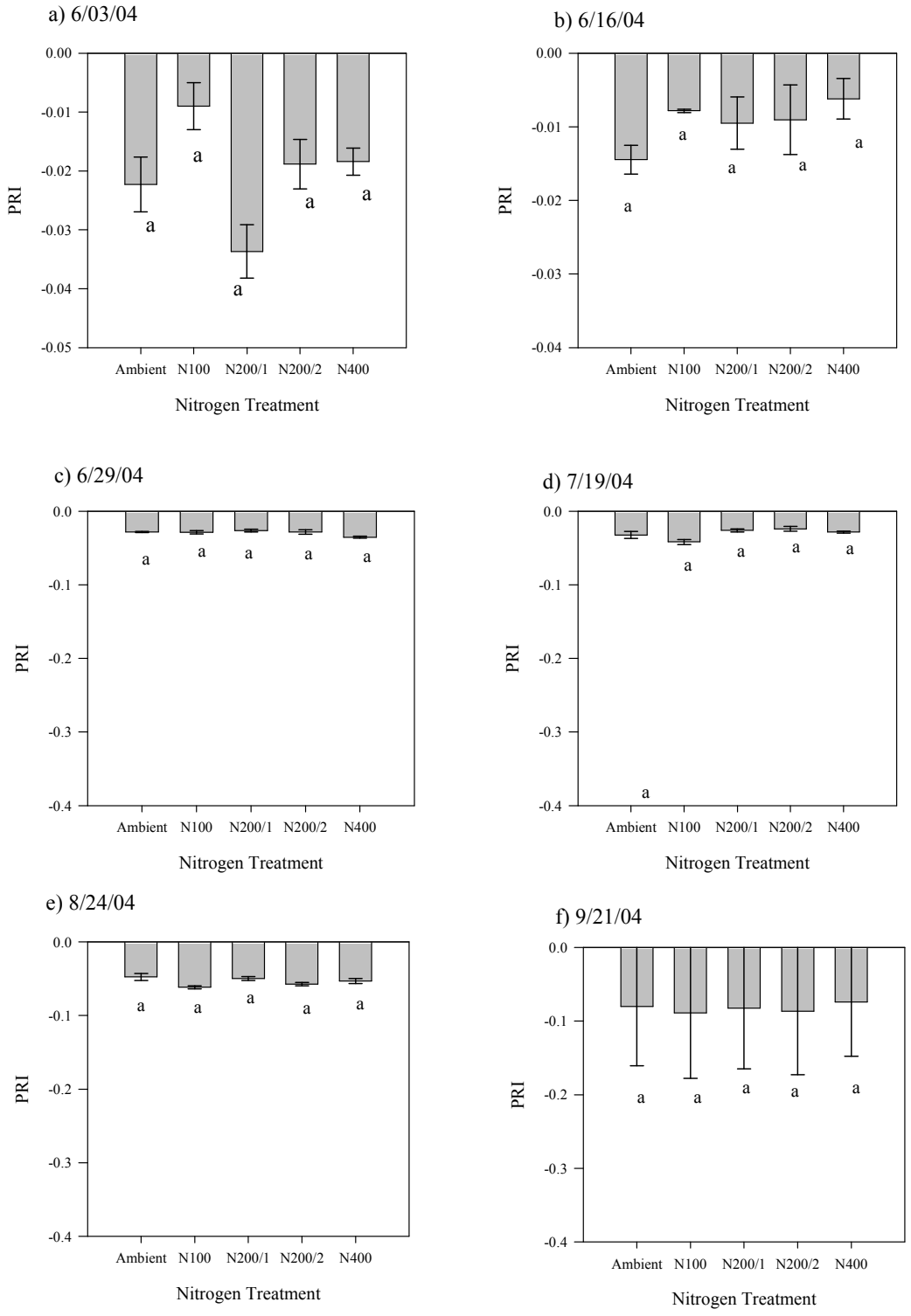

**Figure 3.3.9. Mean $R_{564}/R_{768}$ values and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). Ratio $R_{564}/R_{768}$ was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*PRI*

At the *Phragmites*-dominant site no nitrogen effects were detected according to the PRI index $(R_{531}-R_{570})/(R_{531}+R_{570})$ (Figure 3.3.10). At the *Phragmites*-absent site, however, the PRI index was greater for N100 on 6/29/04 and greater for N200/2D on 9/21/04 (Figure 3.3.11), suggesting that PRI could be useful for detecting nitrogen effects during the end of the growing season.

*NDVI*

Figures 3.3.12 and 3.3.13 show differences in NDVI $(R_{nir}-R_{red})/(R_{nir}+R_{red})$ according to nitrogen treatment for both sites. NDVI was saturated at both sites for each treatment, including ambient conditions, which emphasizes the lush, dense vegetation conditions of the marsh. Only a few nitrogen effects on NDVI were found, including at the end of the growing season, the NDVI for the N200/2D treatment decreased at the *Phragmites*-dominant site (Figure 3.3.12) and increased at the *Phragmites*-absent site (Figure 3.3.13).




a

**Figure 3.3.10. Mean PRI values and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). PRI index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

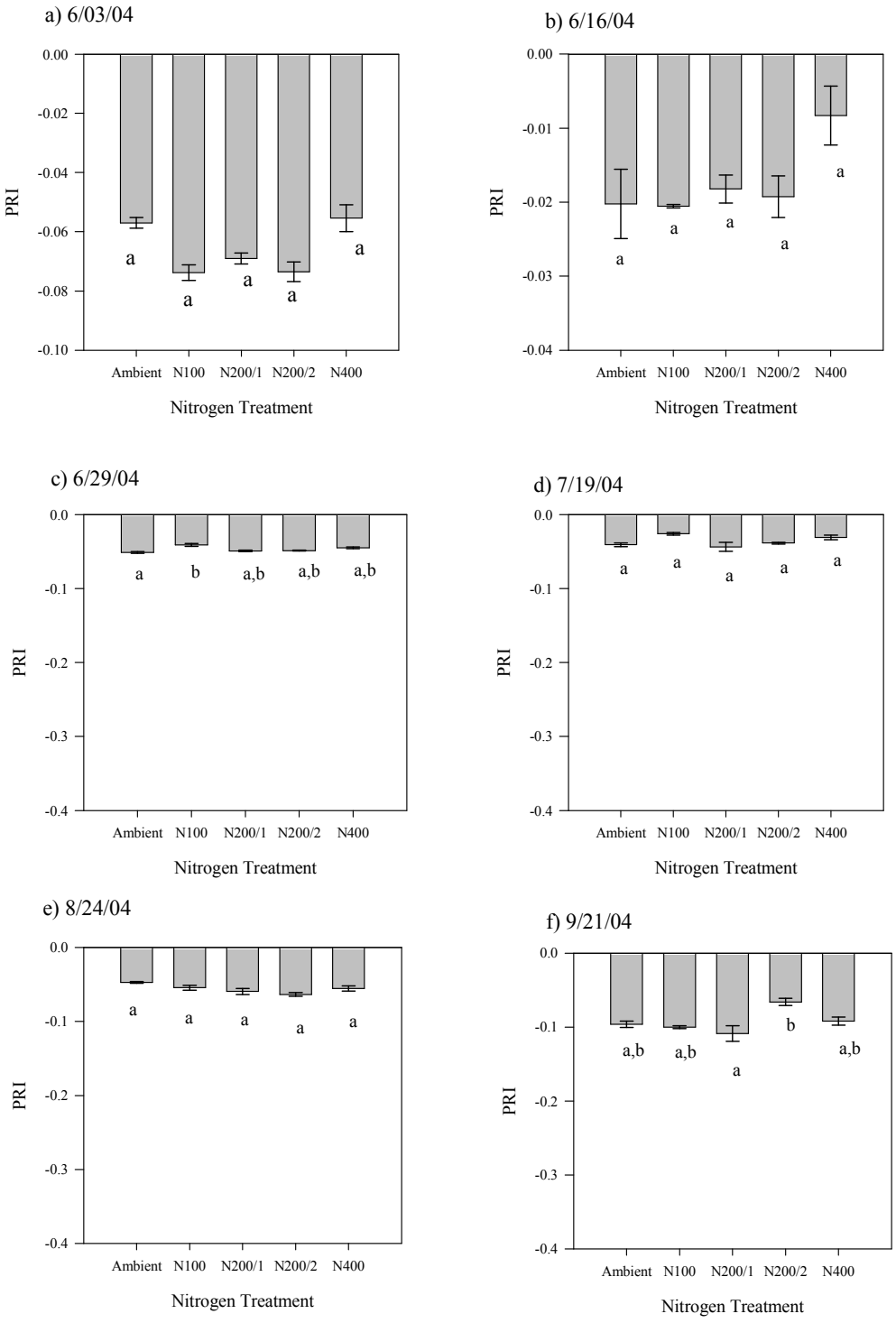



**Figure 3.3.11. Mean PRI values and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). PRI index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

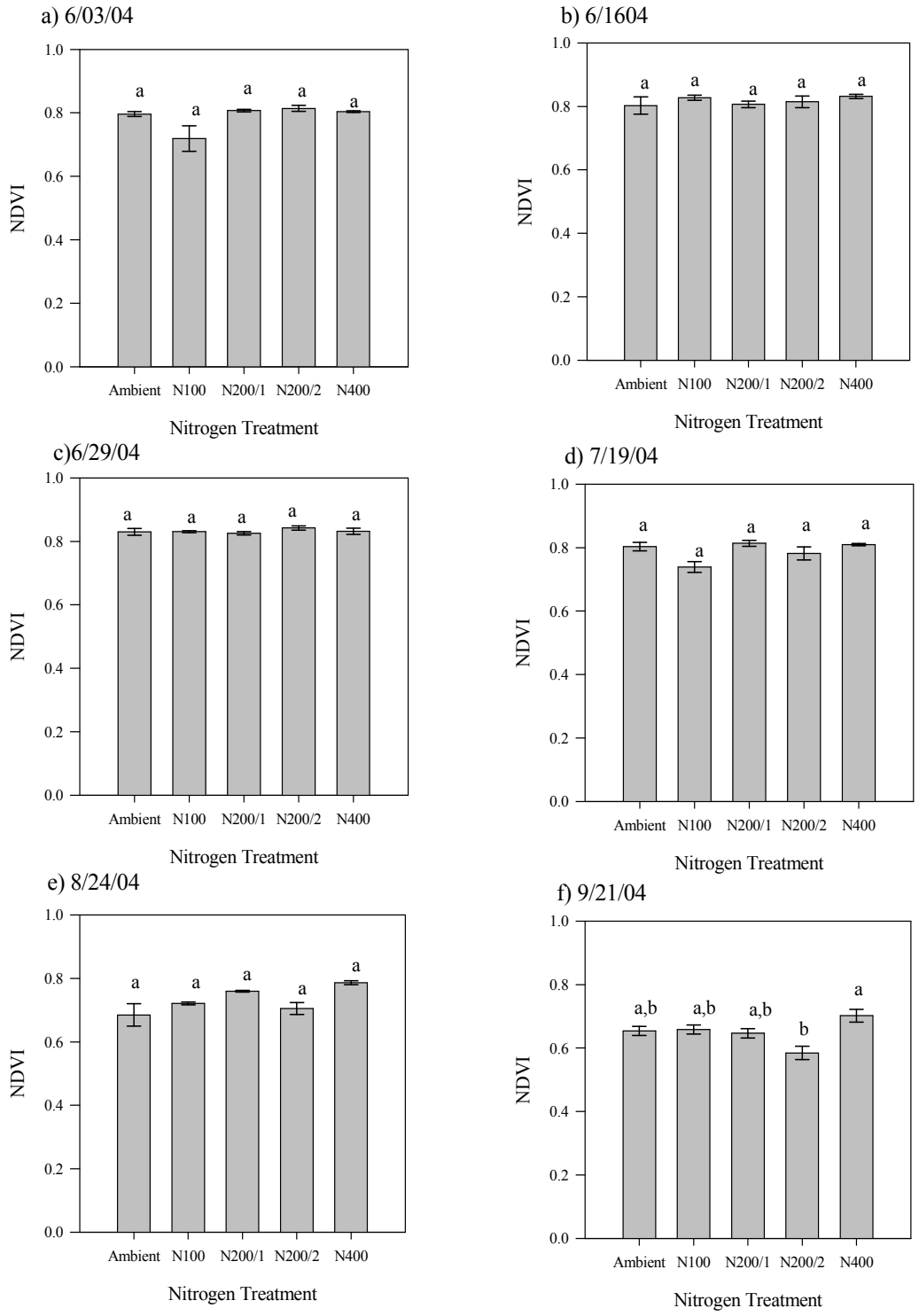



**Figure 3.3.12. Mean NDVI values and standard errors of the *Phragmites*-dominant site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). NDVI index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

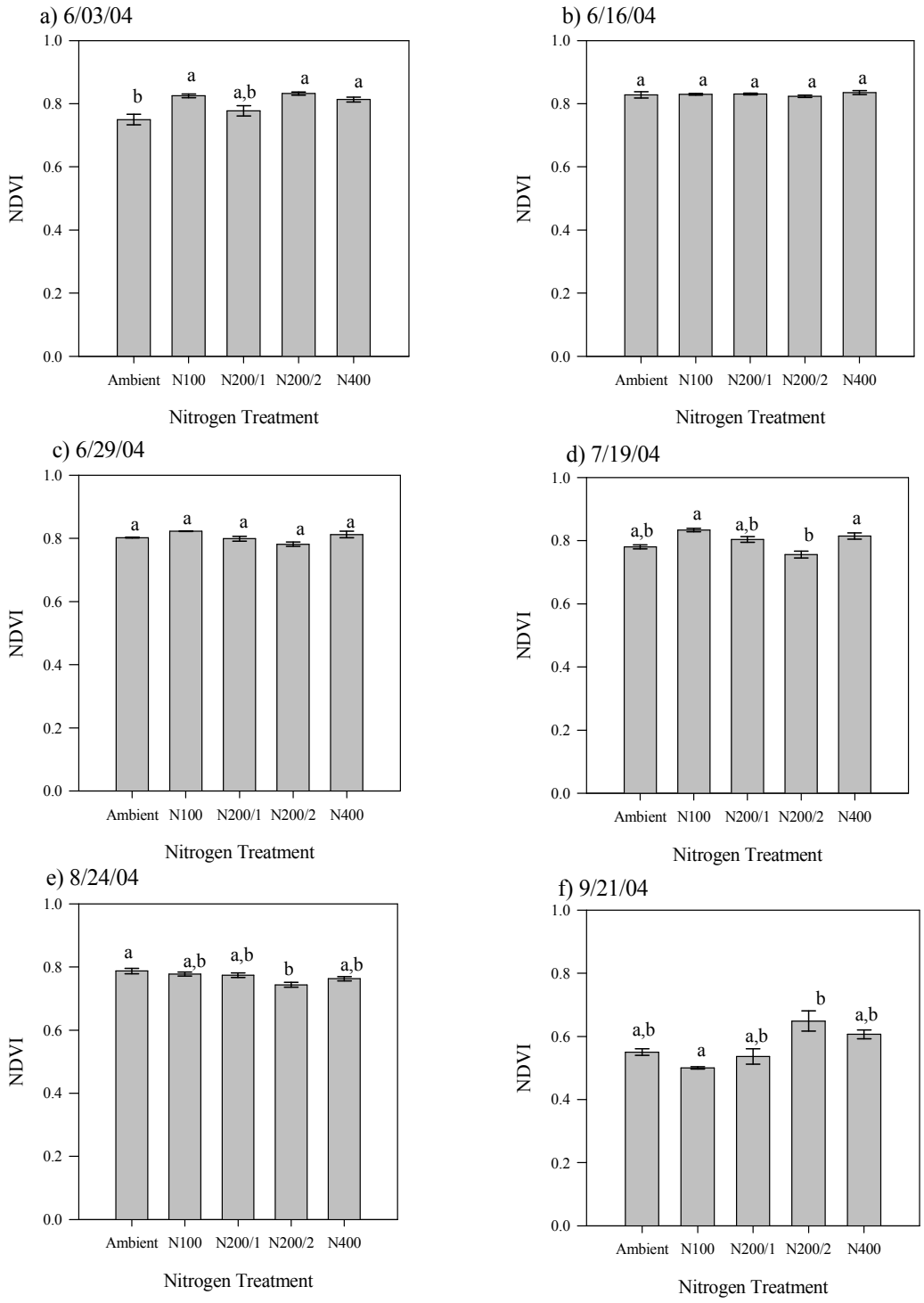



**Figure 3.3.13. Mean NDVI values and standard errors of the *Phragmites*-absent site according to nitrogen treatment over the 2004 growing season. Treatments with different letters indicate a significant difference between treatments ($p<0.05$). NDVI index was the dependent variable in the one-way ANOVA model, with an LSD contrast.**

*3.3.3 Detection of nitrogen and marsh-type effects on canopy reflectance*

To determine if canopy reflectance of a highly diverse marsh was capable of distinguishing between nitrogen treatments, both nitrogen effects and vegetation composition effects at each site and sample date were analyzed. First, reflectance of each site was investigated. Figure 3.3.14 compares the mean reflectance curves for the *Phragmites*-dominant with the *Phragmites*–absent marsh site before fertilization. The figure shows the natural differences in reflectance between the two sites, which suggested the need to analyze treatment effects on canopy reflectance for each site separately.

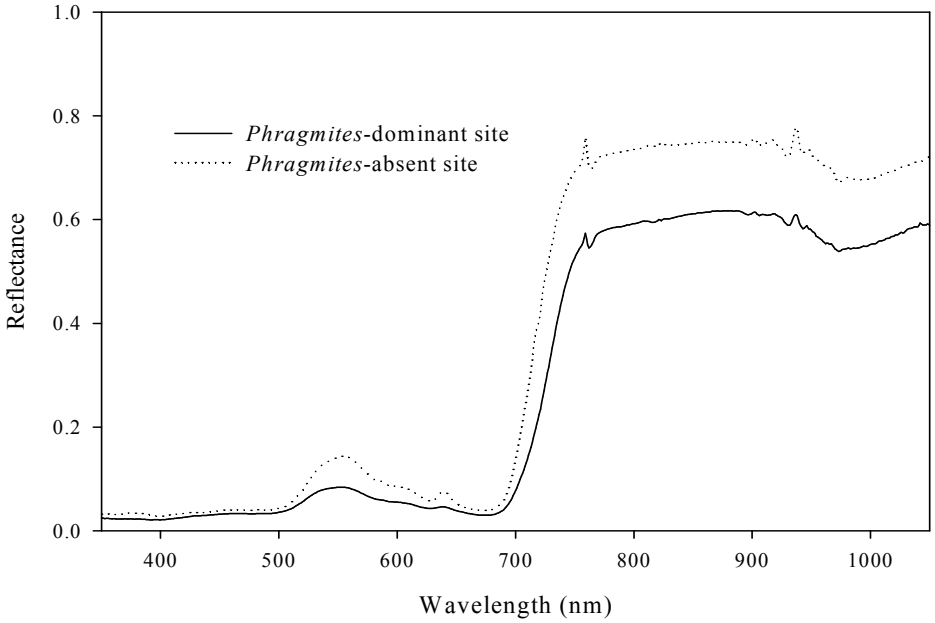



**Figure 3.3.14. Mean reflectance of each marsh site prior to nitrogen fertilization (5/25/04).**

Site, treatment and their interaction were analyzed in ANOVA to determine which spectral bands were most affected by site and treatment effects. Interactions between site and treatment were found in the red at the end of the growing season (9/21/04)

and in the green and red-edge at the beginning of the 2005 season (6/06/05) (Figure 3.3.15).

No nitrogen effect was detected for any spectral band on sample dates between May and August, 2004 (Figure 3.3.16). However there was a nitrogen effect in the NIR on both 9/21/04 and 6/06/05. Due to the site and treatment interaction in the visible range on both dates, only the NIR nitrogen effects were considered.

Site effects on wavebands were very significant for several sample dates across the growing season (Figure 3.3.17). Before fertilization every waveband had a different reflectance at the *Phragmites*-dominant than at the *Phragmites*-absent site (Figure 3.3.17a), which implied the differences between observed vegetative species at the two sites produced different reflectance curves. Throughout the rest of the growing season, site effects were most noticeable in the green, red-edge, and NIR in late-June through late-August (Figures 3.3.17d, e, f, and i), when most species were at their peak. Late in the growing season (9/21/04), both sites were beginning to senesce, so canopy reflectance between the two sites was not different (Figure 3.3.17g).

The addition of nitrogen did not affect any spectral band for any site or date, except at the *Phragmites*-absent site at the end of the growing season (9/21/04) and beginning of the 2005 season (6/06/05) (Figures 3.3.18l and n), indicating that nitrogen is not easily detectable during the peak of growing season.

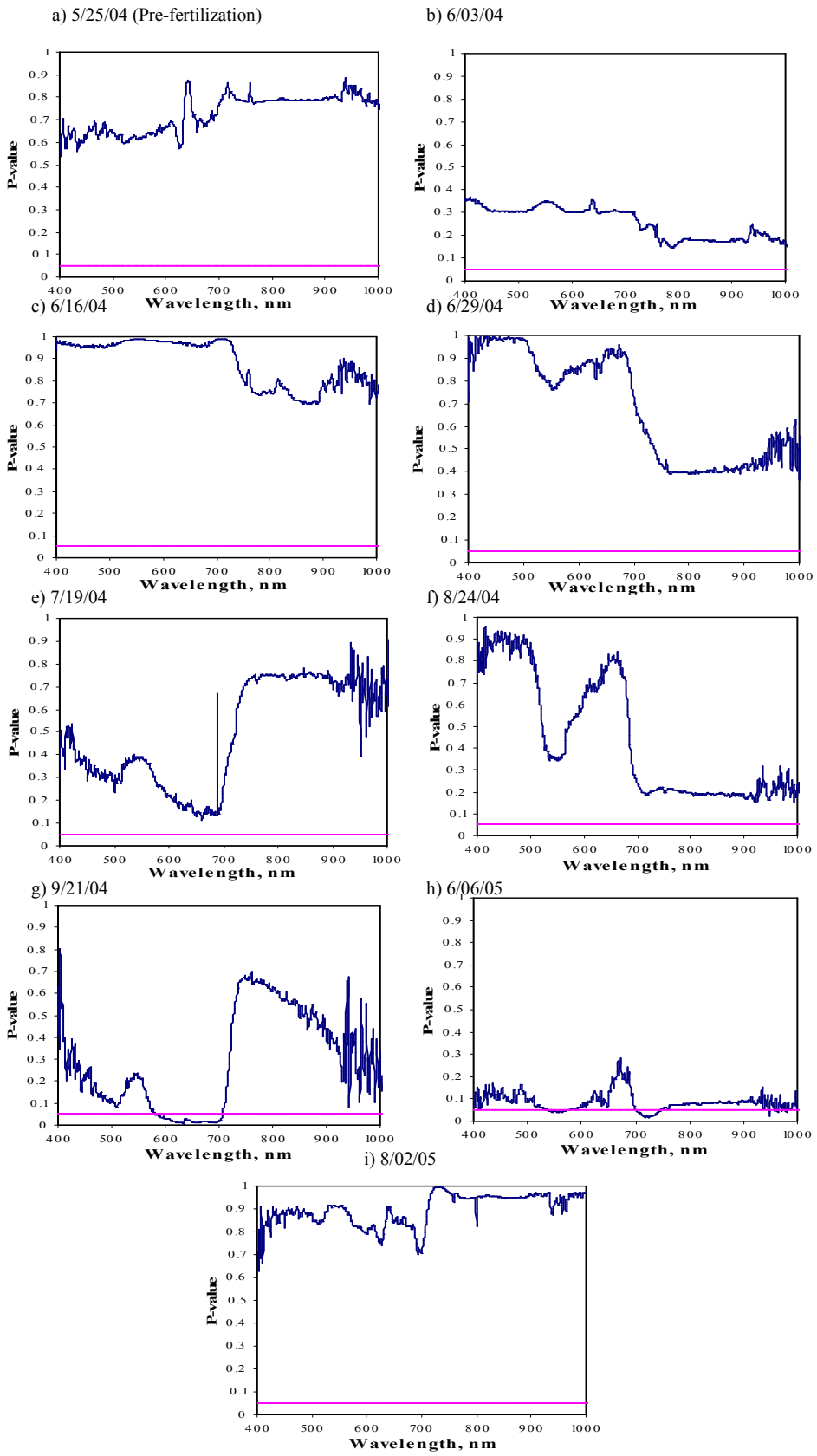



**Figure 3.3.15. Significance of interaction effect between nitrogen treatment and site for all dates. ANOVA model: N trt + site + (N trt x site) (SPSS).**

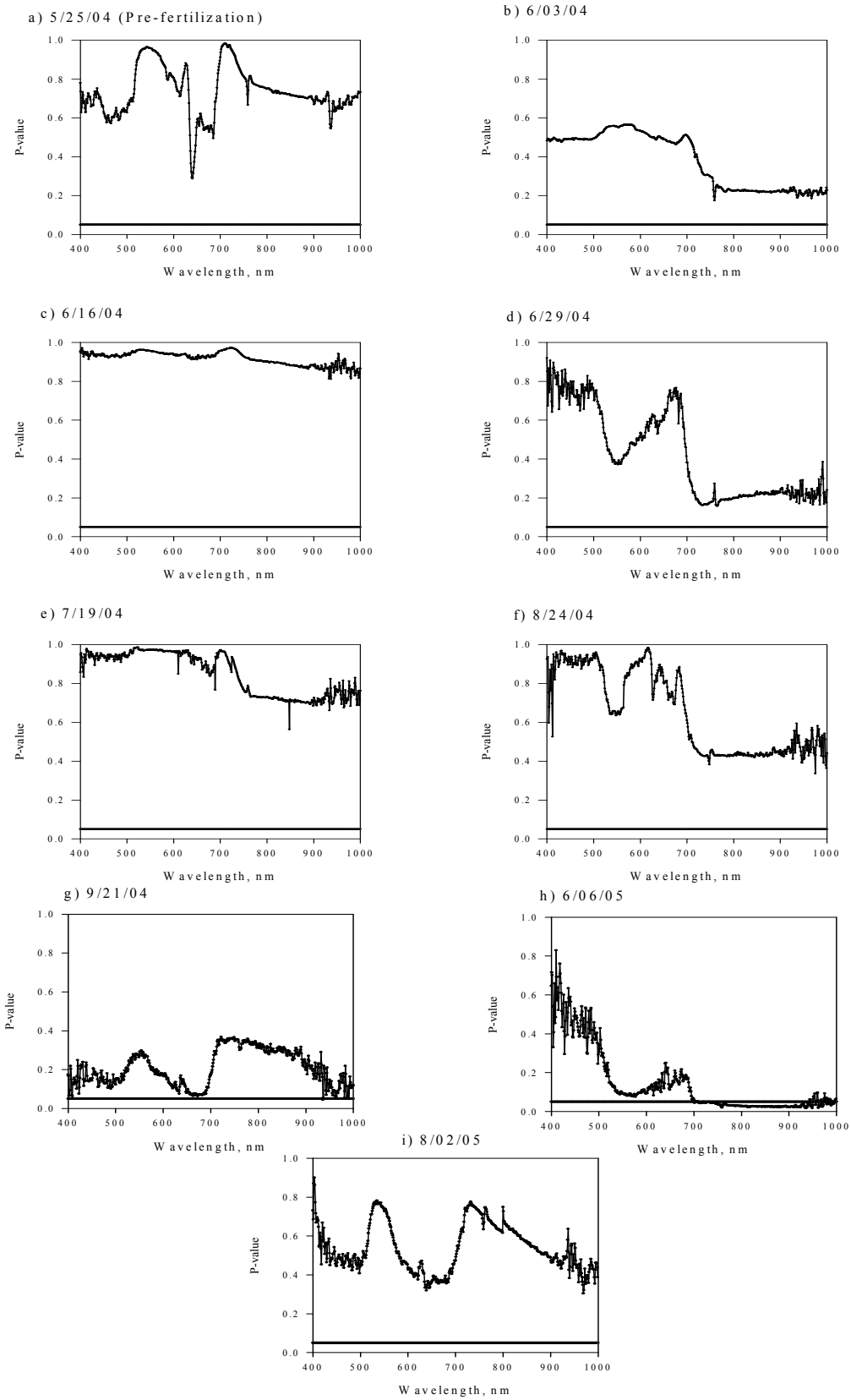



**Figure 3.3.16. Significance of N main effect for all dates as analyzed in ANOVA (SPSS). ANOVA model: Ntrt + site + (Ntrt x site).**

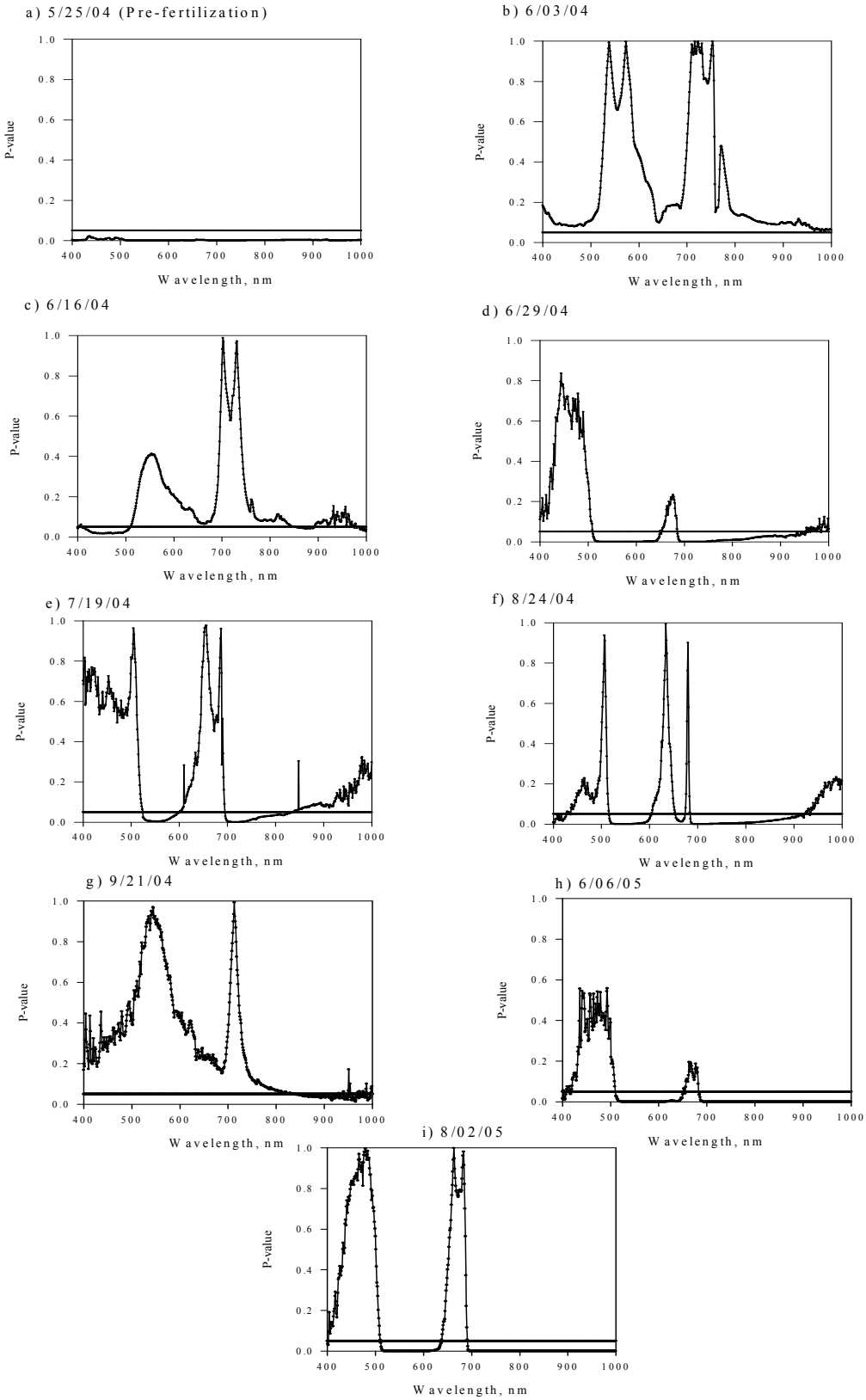
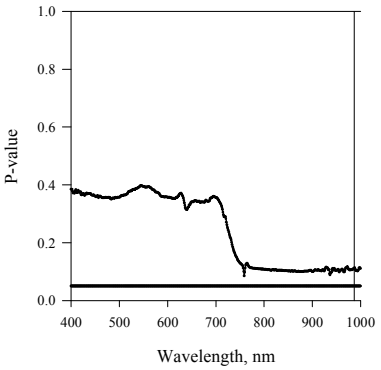
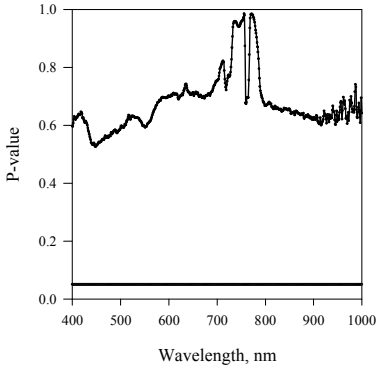



**Figure 3.3.17. Significance of site main effect for all dates as analyzed in ANOVA (SPSS). ANOVA model: Ntrt + site +(Ntrt x site).**

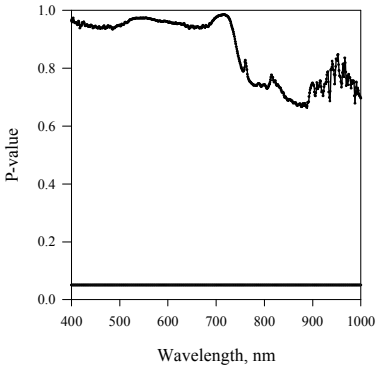
a) 6/03/04 *Phragmites*-dominant site



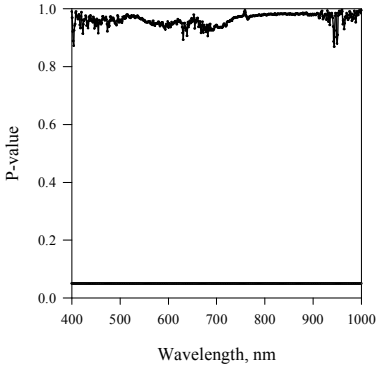

b) 6/03/04 *Phragmites*-absent site



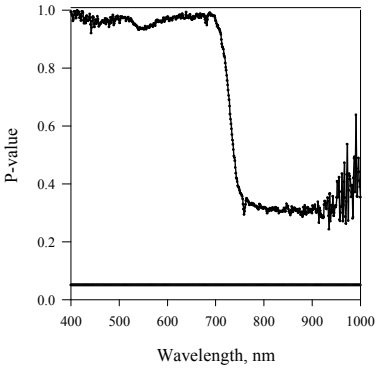

c) 6/16/04 *Phragmites*-dominant site



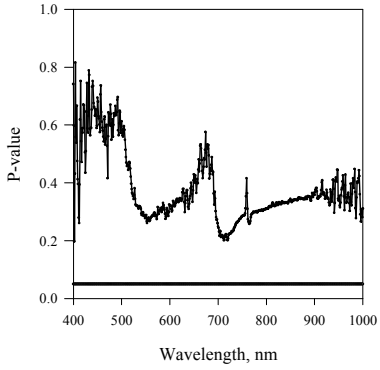

d) 6/16/04 *Phragmites*-absent site



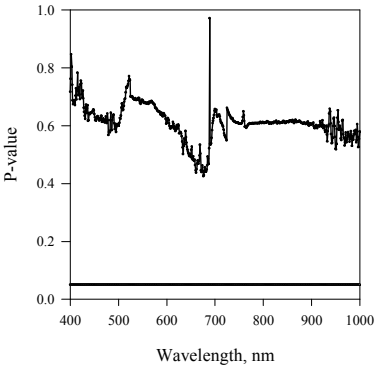

e) 6/29/04 *Phragmites*-dominant site



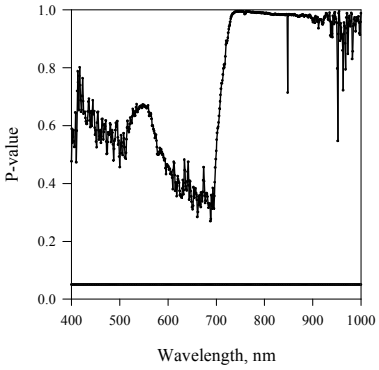

f) 6/29/04 *Phragmites*-absent site




g) 7/19/04 *Phragmites*-dominant site




h) 7/19/04 *Phragmites*-absent site



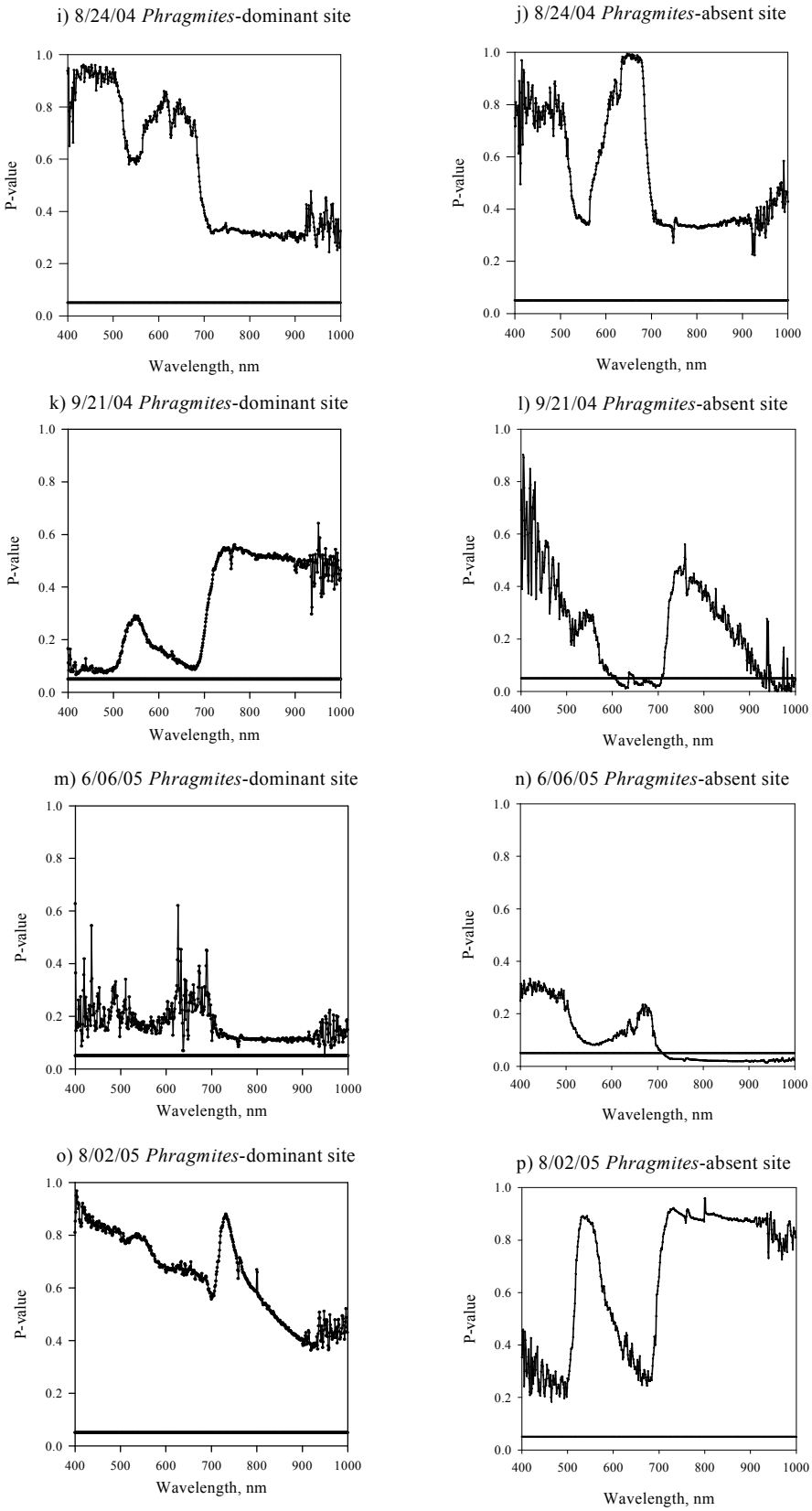


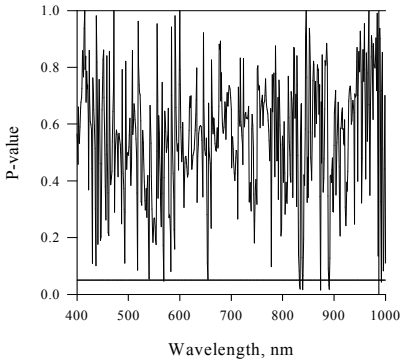

**Figure 3.3.18. Significance of nitrogen treatment main effect for individual sites as analyzed in ANOVA. ANOVA model: reflectance = dependent variable, N trt = fixed factor.**

*3.3.4 Detection of nitrogen effects on transformed canopy reflectance*

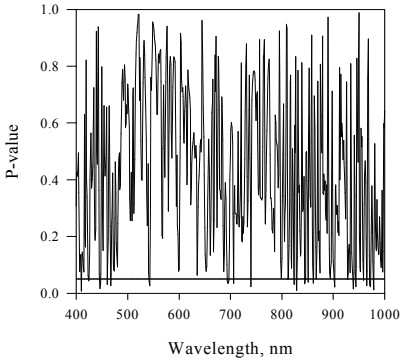
The first and second derivatives of the canopy reflectance were analyzed to determine if nitrogen fertilization affected marsh reflectance. Results from the first derivative analysis were not reported because the second derivative of the reflectance could discriminate more between nitrogen levels and was affected by more spectral bands.

Nitrogen had a significant effect on the second derivative of many spectral bands (Figure 3.3.19), which suggested that the second derivative of reflectance could be a stronger indicator of nitrogen levels than untransformed reflectance. There were more spectral bands affected by nitrogen during the middle growing season (June-August) than at the end (September) (Figure 3.3.20). Figure 3.3.20 summarizes which spectral bands were affected by nitrogen when using the second derivative of reflectance. The site summaries in the chart indicate spectral bands affected by nitrogen in three or more sample dates. In general, nitrogen most consistently affected the second derivative within the 500-750 nm spectrums for both sites, however there were a few spectral bands in the 400-500 and NIR portions of the spectrum for both marsh sites that responded to nitrogen. All significant spectral bands for each site are listed in the Appendix.

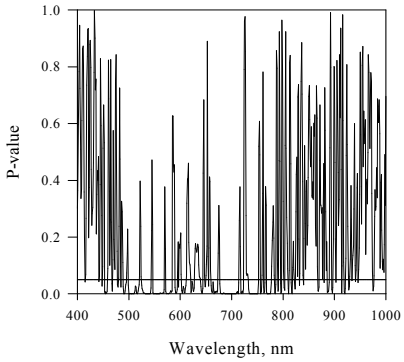
a) 6/03/04 *Phragmites*-dominant site



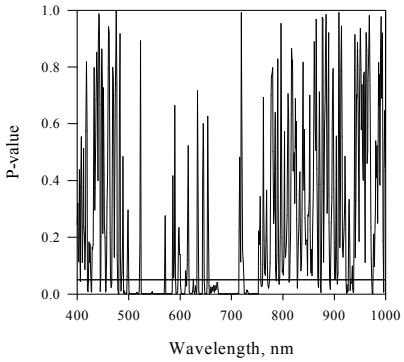

b) 6/03/04 *Phragmites* -absent site



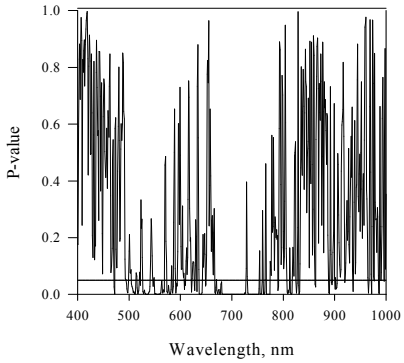

c) 6/16/04 *Phragmites*-dominant site



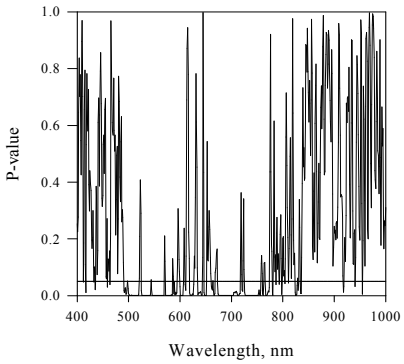

d) 6/16/04 *Phragmites*-absent site



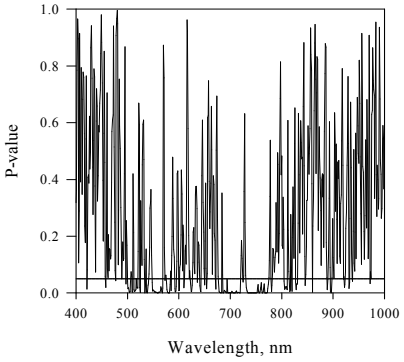

e) 6/29/04 *Phragmites*-dominant site



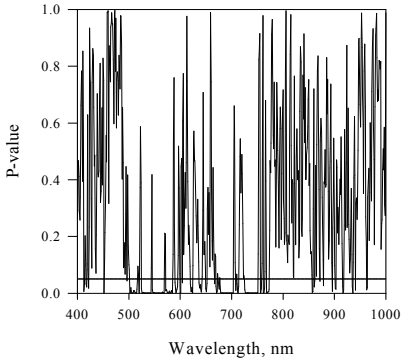

f) 6/29/04 *Phragmites*-absent site




g) 7/19/04 *Phragmites*-dominant site




h) 7/19/04 *Phragmites*-absent site



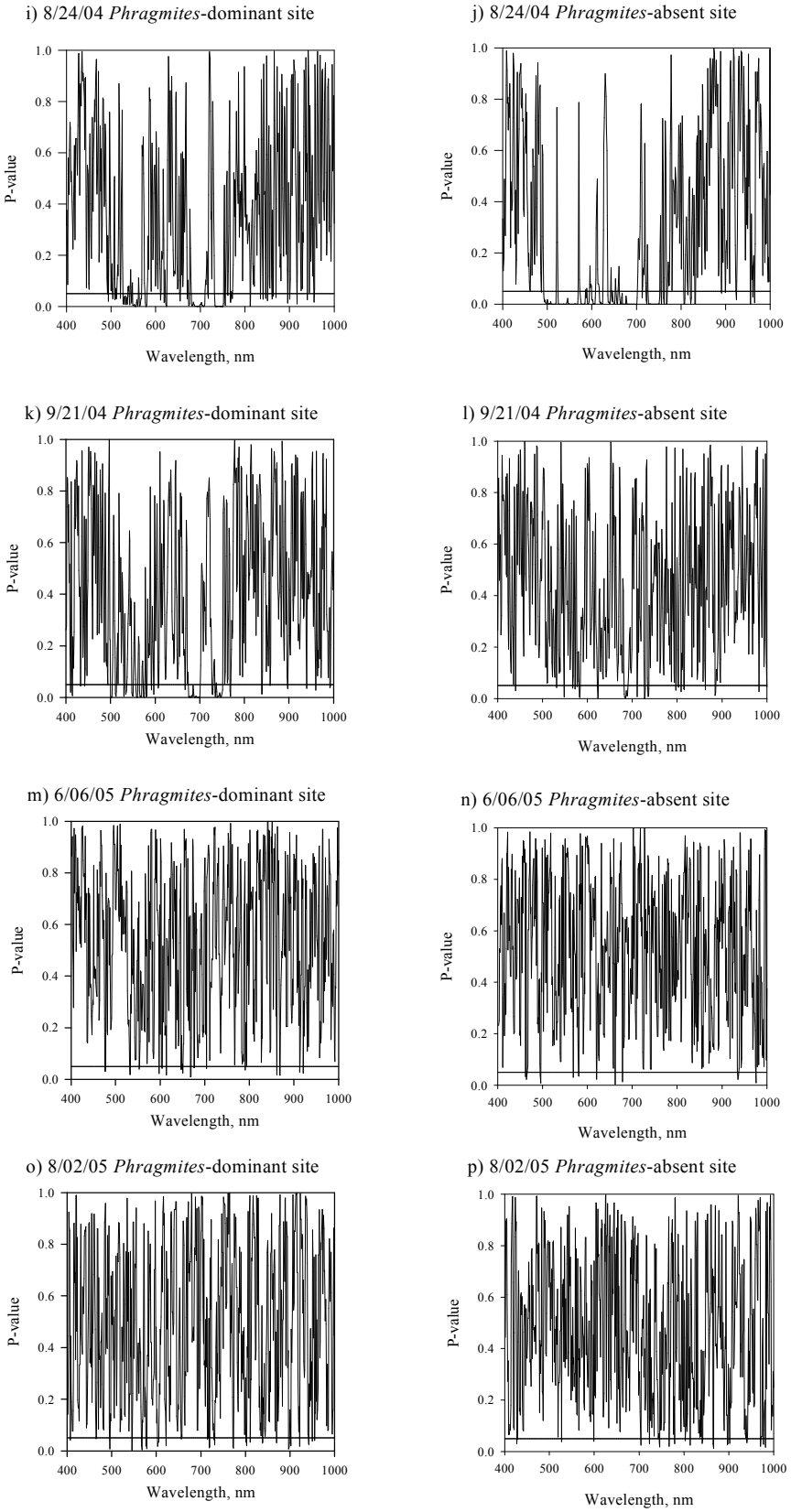



**Figure 3.3.19. Significance of nitrogen treatment main effect for individual sites on the second derivative (Golay) of canopy reflectance as analyzed in an ANOVA model.**

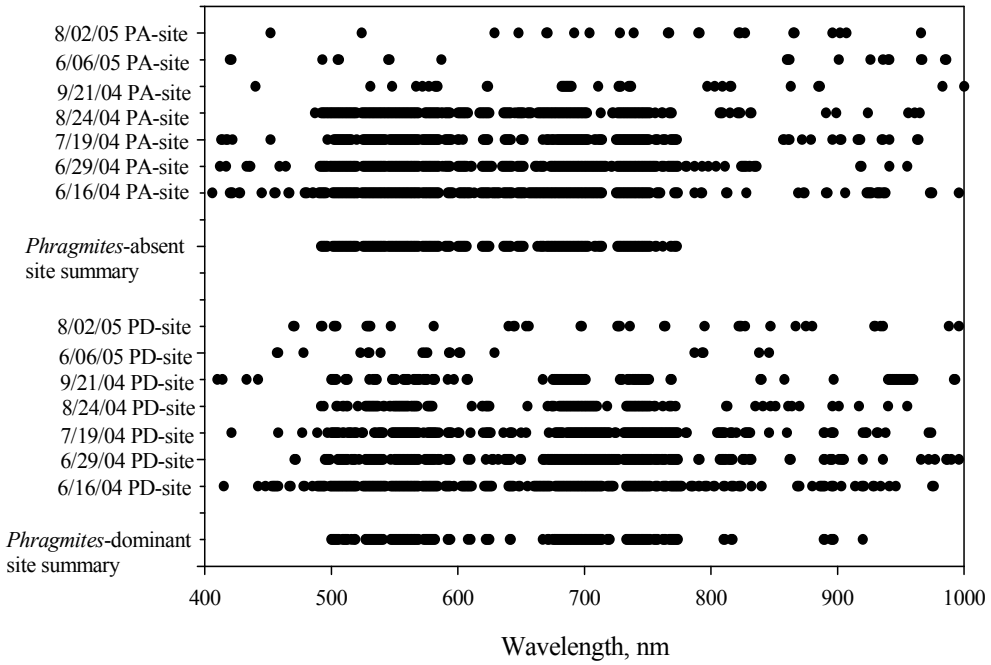



**Figure 3.3.20. Spectral bands identified as significantly affected by N for the second derivative of reflectance (Golay). Site summaries indicate spectral bands affected by nitrogen for three or more dates.**

### *3.4 Partial Least Squares (PLS) Modeling*

Partial least squares (PLS) regressions were used to develop spectroradiometric models predictive of sub-surface water nutrient concentrations and vegetation composition in tidal freshwater marshes.

#### *3.4.1 Prediction of nitrogen and phosphorus in marsh sub-surface water*

Since remote assessment of nutrient concentrations in tidal freshwater marshes would be beneficial, we explored the ability of PLS-regressions to predict sub-surface ammonia, nitrate, total nitrogen and total phosphorus concentrations.

*PLS models of Ammonia*

PLS could not accurately predict ammonia concentrations at the two marsh sites, regardless of transformations employed (Tables 3.4.1 and 3.4.2). The best PLS model used eight spectral bands of untransformed spectra from 9/21/04 that were combined into four PLS-components with an RMSEP of 1.97 and $R^2 = 0.50$ (Figure 3.4.1).

**Table 3.4.1. PLS-regressions for ammonia on *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.71 | 1.97 | 28 | PA 8-9 | 4 | 8 | PA8-9 inaccurate reflectance curve |
| **Norris 1st Derivative** | **Log $NH_3$** | 9.21.04 | 0.70 | 0.37 | 30 | none | 2 | 62 | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.69 | 4.42 | 23 | PD 3,6,8-10; PA 8,12 | 2 | 26 | PD3,6,9-10, PA12 missing $NH_3$ conc; PD8, PA8 high $NH_3$ conc. |
| **Log R** | **Sqrt $NH_3$** | 9.21.04 | 0.66 | 0.57 | 29 | PD 6 | 3 | 16 | PD6 high reflectance |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.66 | 1.99 | 30 | none | 2 | 18 | none |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.63 | 3.68 | 30 | none | 2 | 10 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.61 | 3.70 | 30 | none | 1 | 52 | none |
| **Avg 5 wavelengths** | **none** | 8.24.04 | 0.59 | 2.80 | 29 | PD 1 | 1 | no | PD1 high $NH_3$ concentration |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 9.21.04 | 0.57 | 0.42 | 30 | none | 1 | 19 | none |
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | 0.56 | 2.16 | 28 | PD1; PA7 | 6 | 27 | PD1, PA7 high $NH_3$ conc. |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.51 | 2.51 | 27 | PD1; PA 3,7 | 10 | 29 | PD1, PA7 high $NH_3$ conc; PA3 low $NH_3$ conc. |
| **Truncated spectra (400-950nm)** | **Log $NH_3$** | 8.24.04 | 0.48 | 0.47 | 27 | PD 1,6; PA13 | 6 | 86 | PD6 high reflectance; PD1, PA13 high $NH_3$ conc. |
| **MSC Transformation** | **none** | 8.24.04 | 0.47 | 3.13 | 28 | PD 1,4 | 1 | 92 | PD1 high $NH_3$ conc.; PD4 spiked reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.45 | 1.60 | 26 | PD 1,4,6; PA13 | 1 | 632 | PD6 high refl.; PD4 low refl.; PD1,PA13 high NH3 conc. |
| **Transform 1/R** | **none** | 9.21.04 | 0.43 | 2.45 | 30 | none | 2 | 128 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.42 | 1.63 | 26 | PD 1,4,6; PA13PA | 9 | 542 | PD6 high reflect; PD4 low reflect; PD1, PA13 high $NH_3$ conc. |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.42 | 2.12 | 28 | PD 1,6 | 6 | 46 | PD6 high reflectance; PD1 high concentration |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.42 | 1.67 | 28 | PA 7,11 | 1 | 28 | PA7,11 high $NH_3$ concentration |
| **Log R** | **Sqrt $NH_3$** | 8.24.04 | 0.40 | 0.57 | 26 | PD 1,4,6; PA13 | 1 | 554 | PD6 high reflect; PD4 low reflect; PD1, PA13 high $NH_3$ conc. |
| **Log R** | **none** | 9.21.04 | 0.39 | 2.08 | 29 | PA 7 | 3 | 105 | PA7 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.35 | 4.49 | 30 | none | 3 | 29 | none |

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **Log $NH_3$** | 8.24.04 | 0.35 | 0.56 | 30 | none | 2 | 65 | none |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.34 | 5.69 | 25 | PD 1,15; PA 2,5,11 | 2 | 262 | PD15, PA2,11 high $NH_3$ conc; PD1 low $NH_3$ conc; PA5 missing $NH_3$ conc. |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.34 | 1.71 | 26 | PD 1,2,6; PA13 | 1 | 504 | PD6 high reflect; PD2 low refl.; PD1, PA13 high $NH_3$ conc |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.33 | 4.47 | 30 | none | 3 | 10 | none |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 8.24.04 | 0.33 | 0.56 | 30 | none | 2 | 25 | none |
| **Avg 10 wavelengths** | **none** | 8.24.04 | 0.33 | 1.69 | 27 | PD 1,6; PA13 | 4 | no | PD6 high reflectance; PD1, PA13 high $NH_3$ concentration |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.32 | 6.38 | 26 | PD 1,4,12; PA2 | 6 | 1 | PD1, PA2 high $NH_3$ conc; PD4,12 missing $NH_3$ conc |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.32 | 4.49 | 30 | none | 1 | no | none |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.31 | 4.72 | 30 | none | 5 | no | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.24 | 4.62 | 30 | none | 2 | no | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.24 | 4.73 | 30 | none | 3 | 13 | none |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.23 | 0.11 | 30 | none | 4 | 18 | none |
| **Truncated spectra (400-950nm)** | **Sqrt $NH_3$** | 8.24.04 | 0.23 | 1.06 | 30 | none | 4 | 17 | none |
| **Transform 1/R** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.23 | 0.07 | 27 | PD 1,4,6 | 1 | 364 | PD6 high reflectance; PD4 low reflectance; PD1 high $NH_3$ conc. |
| **Norris 1st Derivative** | **Log $NH_3$** | 8.02.05 | 0.21 | 0.64 | 23 | PD 3,6,9-10; PA 3,8,12 | 1 | 21 | PD3,6,9-10, PA12 missing $NH_3$ conc; PA8 high $NH_3$ conc; PA3 spiked reflect. |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 7.19.04 | 0.19 | 0.49 | 29 | PD 1 | 1 | 18 | PD1 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **4th rt $NH_3$** | 8.24.04 | 0.17 | 0.41 | 30 | none | 4 | 14 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.16 | 7.91 | 29 | PD1 | 2 | 55 | PD1 high $NH_3$ concentration |
| **Truncated spectra, manual test set** | **none** | 8.24.04 | 0.16 | 2.86 | 10 | PD6 | 1 | no | PD6 high reflectance |
| **Truncated spectra, random test set** | **none** | 8.24.04 | 0.09 | 1.65 | 10 | PD 1,6 | 1 | no | PD6 high reflectance; PD1 high $NH_3$ concentration |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.02 | 2.26 | 28 | PD 1,6 | 1 | 22 | PD6 high reflectance; PD1 high $NH_3$ concentration |

**Table 3.4.2. PLS-regression transformations tested on spectrum and ammonia concentration at both sites.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NH_3$) | Truncated, 4th root $NH_3$ | Truncated Sqrt ($NH_3$) | Truncated $Log_{10}$ $NH_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NH_3$) | Log R | Log R, Sqrt ($NH_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NH_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NH_3$) | Excluding NH3 > 8 | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | | |

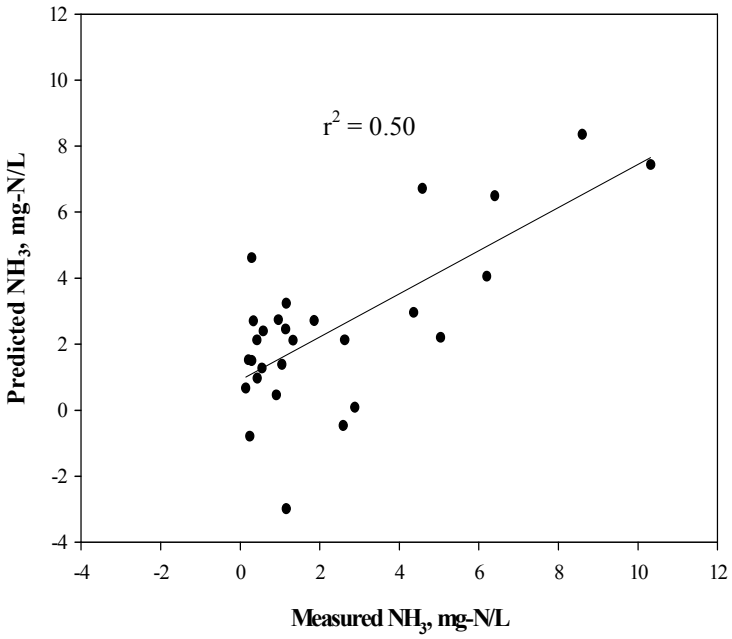



**Figure 3.4.1. Predicted vs measured $NH_3$ PLS-regression for the two marsh sites using untransformed reflectance from 9/21/04 (350-1075nm). Eight spectral bands from 28 samples were used to create four PLS-components with RMSEP = 1.97, r = 0.71.**

PLS could quantify ammonia concentrations at the *Phragmites*-absent and *Phragmites*-dominant site individually. At the *Phragmites*-absent site, PLS-regressions were most successful at correctly predicting ammonia concentrations with transformed (1st and 2nd derivative) spectra (Table 3.4.3), although the untransformed data (9/21/04) using 44 spectral bands that were combined into five PLS-components yielded an $R^2$ of 0.76 and RMSEP of 1.71 (Figure 3.4.2).

**Table 3.4.3. PLS-regression for ammonia at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **Log $NH_3$** | 8.02.05 | 0.91 | 0.24 | 14 | Plot 12 | 2 | 49 | Plot 12 missing $NH_3$ data |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.87 | 1.71 | 15 | none | 5 | 44 | none |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 9.21.04 | 0.84 | 0.31 | 15 | none | 2 | 17 | none |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 8.24.04 | 0.82 | 0.31 | 15 | none | 3 | 38 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.82 | 1.79 | 15 | none | 3 | 12 | none |
| **Norris 1st Derivative** | **Log $NH_3$** | 9.21.04 | 0.65 | 0.44 | 15 | none | 2 | 24 | none |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.58 | 2.76 | 5 | none | 2 | no | Remaining 10 plots used for calibration |
| **Log R** | **none** | 9.21.04 | 0.58 | 2.56 | 15 | none | 1 | 12 | none |
| **Truncated spectra (400-950nm)** | **Log $NH_3$** | 8.24.04 | 0.56 | 0.43 | 12 | Plots 2,13,14 | 1 | 476 | Plots 2,14 high reflect; Plot 13 high $NH_3$ |
| **Truncated spectra (400-950nm)** | **4th rt $NH_3$** | 8.24.04 | 0.54 | 0.24 | 12 | Plots 2,13,14 | 1 | 482 | Plots 2,14 high reflect; Plot 13 high $NH_3$ |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.54 | 1.22 | 14 | Plot 13 | 2 | 78 | Plot 13 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | 0.52 | 5.22 | 15 | none | 5 | 12 | none |
| **Transform 1/R** | **none** | 9.21.04 | 0.52 | 2.84 | 15 | none | 1 | 3 | none |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.49 | 0.05 | 12 | Plots 2,13,14 | 1 | 472 | Plots 2,14 high reflect; Plot 13 high $NH_3$ |
| **Truncated spectra (400-950nm)** | **Sqrt $NH_3$** | 8.24.04 | 0.49 | 0.51 | 12 | Plots 2,13,14 | 1 | 469 | Plots 2,14 high reflect; Plot 13 high $NH_3$ |
| **Transform 1/R** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.48 | 0.05 | 14 | Plot 13 | 4 | 21 | Plot 13 high $NH_3$ concentration |
| **Log R** | **Sqrt $NH_3$** | 9.21.04 | 0.46 | 0.83 | 15 | none | 2 | 5 | none |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.40 | 1.31 | 14 | Plot 13 | 1 | 24 | Plot 13 high $NH_3$ concentration |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.39 | 1.33 | 14 | Plot 13 | 2 | 22 | Plot 13 high $NH_3$ concentration |

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **Sqrt $NH_3$** | 8.24.04 | 0.37 | 0.53 | 13 | Plots 2,13 | 1 | 381 | Plot 2 high reflect; Plot 13 high $NH_3$ |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.37 | 1.33 | 14 | Plot 13 | 1 | 20 | Plot 13 high $NH_3$ concentration |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.37 | 1.33 | 14 | Plot 13 | 1 | 19 | Plot 13 high $NH_3$ concentration |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.37 | 0.37 | 14 | Plot 7 | 3 | 6 | Plot 7 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.33 | 0.75 | 12 | Plots 2,11,13 | 1 | 31 | Plot 2 high reflect; Plots 11,13 high $NH_3$ |
| **Norris 1st Derivative** | **Log $NH_3$** | 8.24.04 | 0.32 | 0.54 | 15 | none | 2 | 7 | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.31 | 1.34 | 14 | Plot 13 | 1 | 25 | Plot 13 high $NH_3$ concentration |
| **Transform 1/R** | **none** | 8.24.04 | 0.27 | 1.43 | 13 | Plots 2,13 | 1 | 97 | Plot 2 high reflect; Plot 13 high $NH_3$ |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.24 | 2.17 | 15 | none | 1 | 13 | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.20 | 1.30 | 14 | Plot 2 | 2 | 8 | Plot 2 high $NH_3$ concentration |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.20 | 3.00 | 5 | none | 2 | no | Remaining 10 plots used for calibration |
| **Golay 2nd Derivative, avg 10** | **Log $NH_3$** | 7.19.04 | 0.19 | 0.24 | 14 | Plot 2 | 1 | 8 | Plot 2 high $NH_3$ concentration |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.16 | 1.44 | 14 | Plot 13 | 1 | no | Plot 13 high $NH_3$ concentration |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.14 | 5.64 | 14 | Plot 3 | 1 | 49 | Plot 3 high reflectance curve |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.13 | 1.45 | 14 | Plot 13 | 1 | no | Plot 13 high $NH_3$ concentration |
| **MSC Transformation** | **none** | 8.24.04 | 0.12 | 1.41 | 14 | Plot 13 | 1 | 9 | Plot 13 high $NH_3$ concentration |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.08 | 1.52 | 14 | Plot 13 | 1 | no | Plot 13 high $NH_3$ concentration |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.05 | 2.34 | 15 | none | 1 | no | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.03 | 10.46 | 14 | Plot 12 | 1 | no | Plot 12 missing $NH_3$ data |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | -0.13 | 7.56 | 15 | none | 1 | no | none |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | -0.35 | 15.27 | 14 | Plot 5 | 1 | no | Plot 5 missing $NH_3$ data |

**Table 3.4.4. PLS-regression transformations tested on spectrum and ammonia concentrations at the *Phragmites*-absent site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NH_3$) | Truncated, 4th root $NH_3$ | Truncated Sqrt ($NH_3$) | Truncated $Log_{10}$ $NH_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NH_3$) | Log R | Log R, Sqrt ($NH_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NH_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NH_3$) | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | |

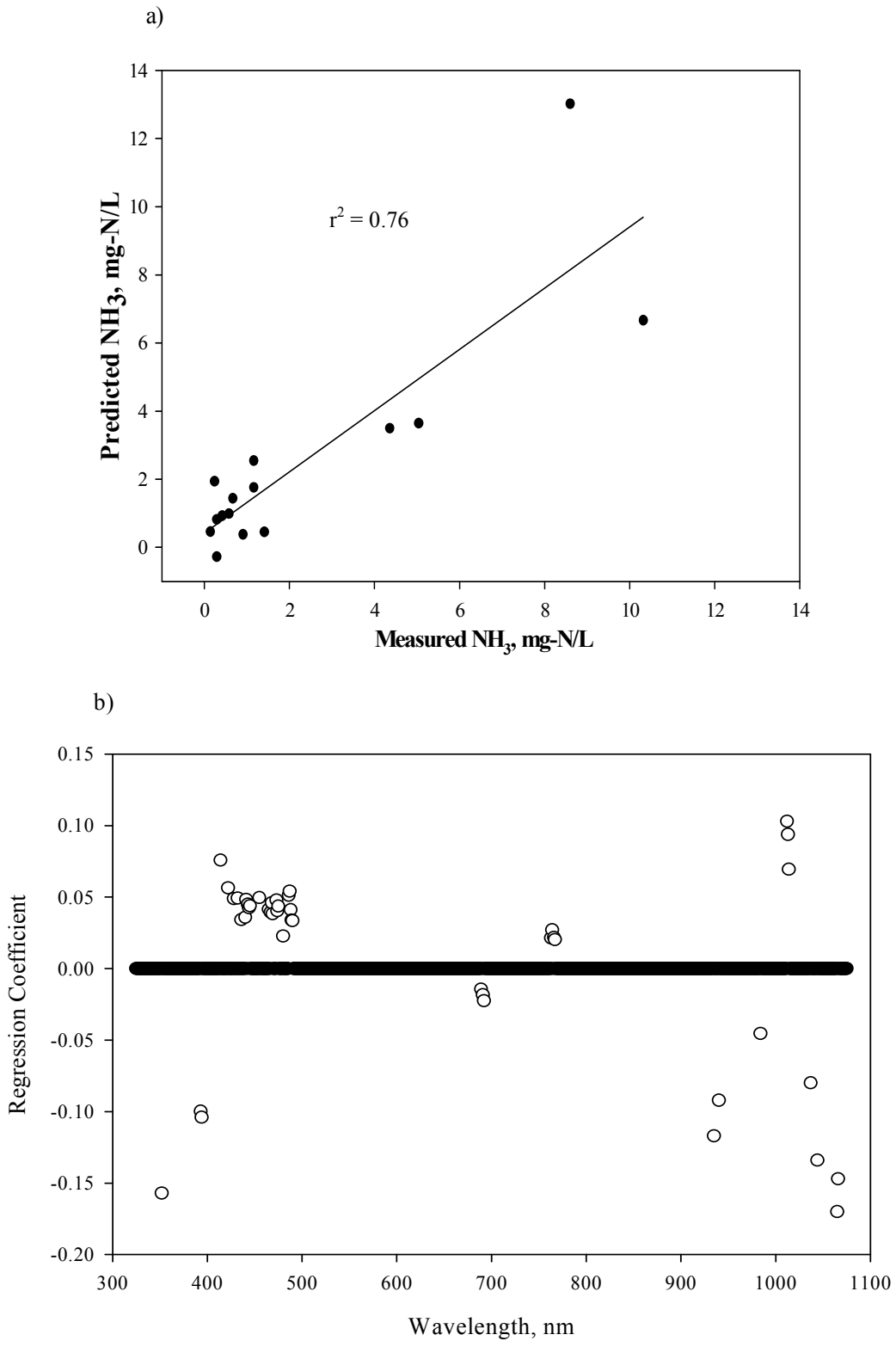



**Figure 3.4.2. (a) Predicted vs measured ammonia PLS-regression which used 44 spectral bands to form five PLS-components with r = 0.87 and RMSEP of 1.71 for the *Phragmites*-absent site, 9/21/04 data. (b) Loading plot of regression coefficients for the PLS-regression.**

The best PLS model at the *Phragmites*-absent site used the 1st derivative of the spectra and the log of ammonia concentration for a more normal distribution (Figure 3.4.3). Two PLS-components were created from the 49 spectral bands used in the model with $R^2 = 0.83$ and an RMSEP of 0.24.

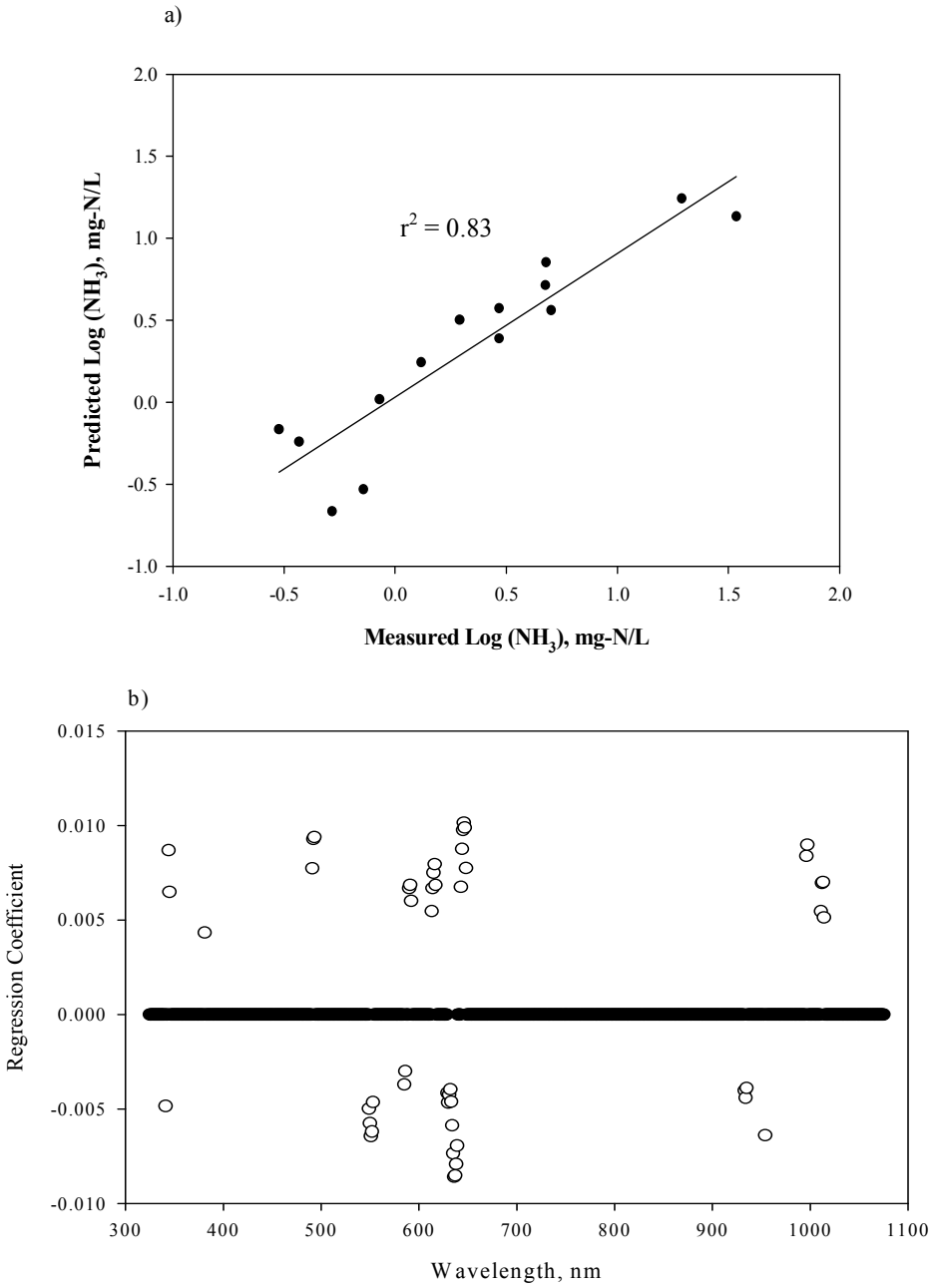



**Figure 3.4.3. (a) *Phragmites*-absent site predicted vs measured log of ammonia PLS-regression using 49 spectral bands of the 1st derivative of the 8/02/05 reflectance to form two PLS-components with r = 0.91 and RMSEP of 0.24. (b) Loading plot of regression coefficients for the PLS-regression.**

PLS was able to quantify ammonia concentrations at the *Phragmites*-dominant site with untransformed spectra during August and September of both years (Table 3.4.5). The most predictive model at the *Phragmites*-dominant site used untransformed spectra (8/02/05) and ten spectral bands in the visible red to form six PLS-components with RMSEP of 1.65 and $R^2 = 0.96$ (Figure 3.4.4).

Summaries of spectral bands used in each PLS-regression are given for combined marsh sites, and individual sites (Tables 3.4.5a, 3.4.6a, and 3.4.7a). Models for the two marsh sites used only a few spectral bands in the green and near-infrared in ten or more regressions (Figure 3.4.5b). At the *Phragmites*-absent site spectral bands used in ten or more PLS-regressions were generally located in the blue and green wavebands (Figure 3.4.6b). The *Phragmites*-dominant site displayed the most spectral bands used in ten or more PLS-regressions, particularly in the green, red-edge, and near-infrared (Figure 3.4.7b). A list of the illustrated bands, significant to ten or more regressions, can be found in the Appendix.

**Table 3.4.5. PLS-regression for ammonia at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.98 | 1.65 | 10 | Plots 3,6,8-10 | 6 | 10 | Plots 3,6,9-10 missing $NH_3$; Plot 8 high $NH_3$ |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.88 | 0.80 | 14 | Plot 10 | 2 | 103 | Plot 10 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **Sqrt $NH_3$** | 8.24.04 | 0.77 | 0.61 | 14 | Plot 1 | 5 | 30 | Plot 1 high $NH_3$ concentration |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.73 | 1.18 | 14 | Plot 6 | 3 | 278 | Plot 6 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.72 | 0.07 | 14 | Plot 1 | 4 | 35 | Plot 1 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **4th root $NH_3$** | 8.24.04 | 0.70 | 0.26 | 14 | Plot 1 | 4 | 36 | Plot 1 high $NH_3$ concentration |
| **Norris 1st Derivative** | **Log $NH_3$** | 8.02.05 | 0.63 | 0.55 | 11 | Plots 3,6,9-10 | 1 | 97 | Plots 3,6,9-10 missing $NH_3$ concentration |
| **Golay 2nd Derivative, avg 10** | **Log NH3** | 8.24.04 | 0.62 | 0.45 | 15 | none | 1 | 42 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.59 | 4.98 | 15 | none | 1 | 98 | none |
| **Golay 2nd Derivative, avg 10** | **Log NH3** | 9.21.04 | 0.57 | 0.38 | 15 | none | 2 | 5 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.56 | 5.06 | 15 | none | 1 | 82 | none |
| **Norris 1st Derivative** | **Log $NH_3$** | 8.24.04 | 0.54 | 0.48 | 15 | none | 1 | 35 | none |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.53 | 5.09 | 15 | none | 1 | 92 | none |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.52 | 3.23 | 5 | Plot 6 | 1 | no | Remaining 9 plots used for calib. |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.51 | 8.14 | 12 | Plots 1,4,12 | 2 | 36 | Plot 1 high NH3 conc; Plots 4,12 missing $NH_3$ |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.51 | 5.16 | 15 | none | 1 | 89 | none |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.51 | 5.16 | 15 | none | 1 | 90 | none |
| **Golay 2nd Derivative, avg 10** | **Log NH3** | 7.19.04 | 0.49 | 0.58 | 15 | none | 2 | 148 | none |
| **Log R** | **none** | 9.21.04 | 0.49 | 1.79 | 15 | none | 2 | 228 | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.48 | 5.26 | 15 | none | 1 | 96 | none |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.48 | 5.27 | 15 | none | 1 | 105 | none |

| Spectra Transformations | $NH_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **Square root NH3** | 9.21.04 | 0.47 | 0.58 | 15 | none | 1 | 154 | none |
| **Avg 5 wavelengths** | **none** | 8.24.04 | 0.45 | 5.78 | 14 | Plot 4 | 2 | 80 | Plot 4 low reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.43 | 6.88 | 13 | Plots 1,15 | 2 | 353 | Plot 1 highest $NH_3$ conc; Plot 15 lowest $NH_3$ |
| **Truncated spectra (400-950nm)** | **Log $NH_3$** | 8.24.04 | 0.43 | 0.57 | 15 | none | 9 | no | none |
| **Untransformed (350-1075nm)** | **Discrim. Analysis** | 8.24.04 | 0.41 | 0.86 | 13 | Plots 4,6 | 1 | 79 | Plot 4 low reflect.; 6 high $NH_3$ conc. |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.41 | 1.86 | 13 | Plots 1,6 | 1 | 5 | Plots 1,6 high $NH_3$ conc. |
| **Transform 1/R** | **none** | 9.21.04 | 0.41 | 1.83 | 15 | none | 1 | 277 | none |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.41 | 2.10 | 15 | none | 1 | 39 | none |
| **Transform 1/R** | **none** | 8.24.04 | 0.40 | 1.94 | 12 | Plots 1,4,6 | 1 | 517 | Plots 1,6 high $NH_3$ conc; Plot 4 low reflect. |
| **Transform 1/R** | **Arcsine sqrt ($NH_3$)** | 8.24.04 | 0.39 | 0.06 | 12 | Plots 1,4,6 | 1 | 337 | Plots 1,6 high $NH_3$ conc; Plot 4 low reflect. |
| **Avg 10 wavelengths** | **none** | 8.24.04 | 0.39 | 5.82 | 15 | none | 2 | 164 | none |
| **Log R** | **Sqrt NH3** | 8.24.04 | 0.38 | 0.63 | 12 | Plots 1,4,6 | 2 | 264 | Plots 1,6 high $NH_3$ conc; Plot 4 low reflect. |
| **Norris 1st Derivative** | **Log $NH_3$** | 9.21.04 | 0.38 | 0.47 | 15 | none | 1 | 39 | none |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.37 | 5.70 | 15 | none | 2 | 11 | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.37 | 5.98 | 14 | Plot 4 | 2 | 278 | Plot 4 low reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.34 | 5.78 | 15 | none | 2 | 201 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.32 | 20.83 | 13 | Plots 5,10 | 1 | 53 | Plot 5 high reflectance; Plot 10 low reflectance |
| **MSC Transformation** | **none** | 8.24.04 | 0.20 | 6.76 | 15 | none | 2 | 23 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.19 | 6.46 | 14 | Plot 4 | 2 | 162 | Plot 4 low reflectance |
| **Untransformed (350-1075nm)** | **Excluding $NH_3$ >8** | 8.24.04 | 0.17 | 2.12 | 13 | Plots 1,6 | 1 | no | Plots 1,6 $NH_3$ concentration > 8mg/L |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.10 | 6.01 | 4 | Plot 6 | 1 | no | Remaining 10 plots used for calib. |
| **PLS2 Untransformed (350-1075)** | **$NH_3$, $NO_3$** | 8.24.04 | 0.09 | 6.11 | 15 | none | 1 | no | none |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | -0.32 | 2.05 | 14 | Plot 1 | 1 | no | Plot 1 high $NH_3$ concentration |
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | -0.37 | 4.98 | 15 | none | 1 | no | none |

**Table 3.4.6. PLS-regression transformations tested on ammonia concentrations at the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NH_3$) | Truncated, 4th root $NH_3$ | Truncated Sqrt ($NH_3$) | Truncated $Log_{10}$ $NH_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NH_3$) | Log R | Log R, Sqrt ($NH_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NH_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NH_3$) | Excluding NH3 > 8 | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | | |

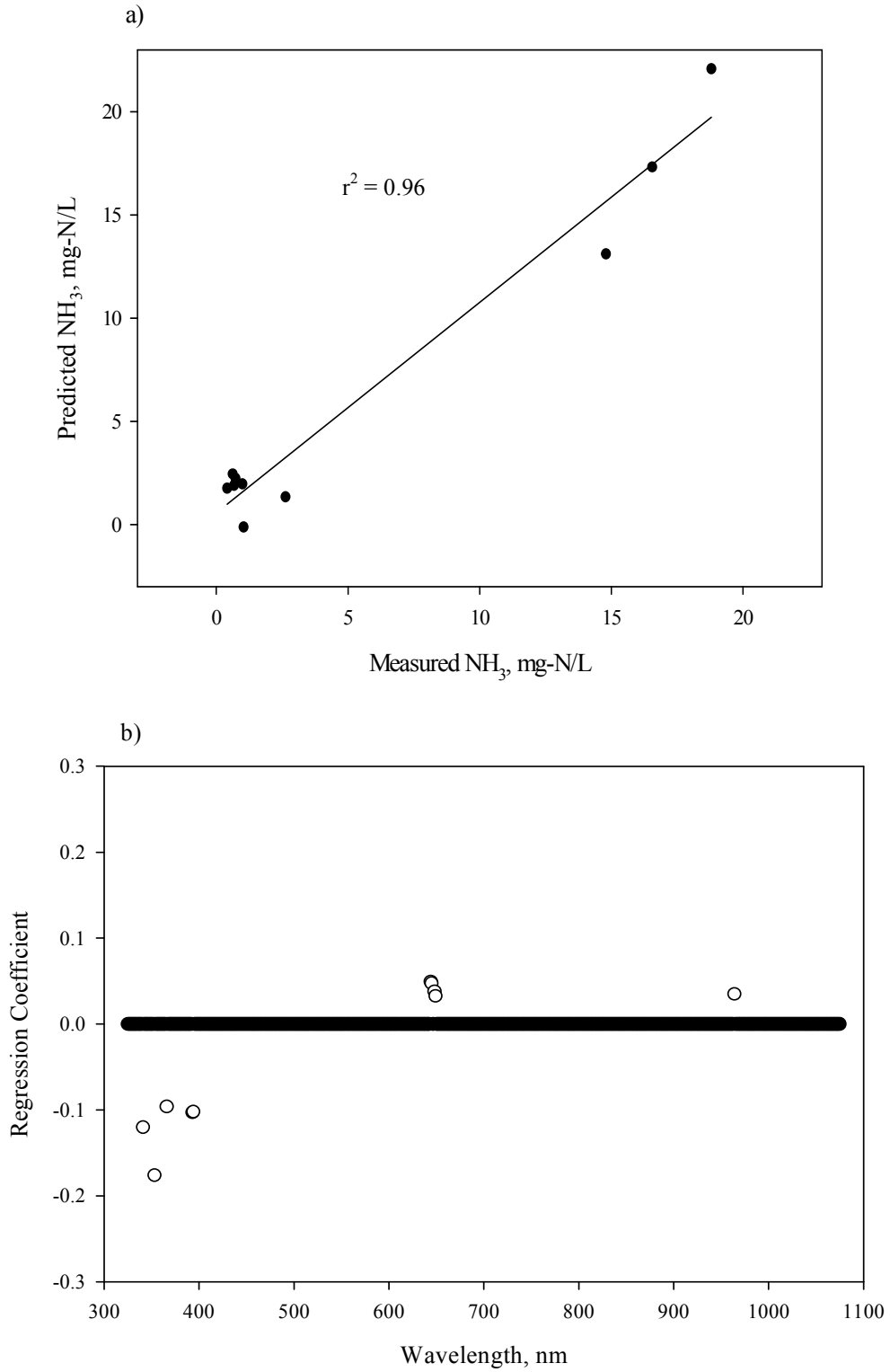



**Figure 3.4.4. (a) Predicted vs measured ammonia PLS-regression at the *Phragmites*-dominant site which used ten spectral bands from 8/02/05 data to form six PLS-components with r = 0.98 and RMSEP = 1.65. (b) Loading plot of regression coefficients vs wavelength for the PLS-regression.**

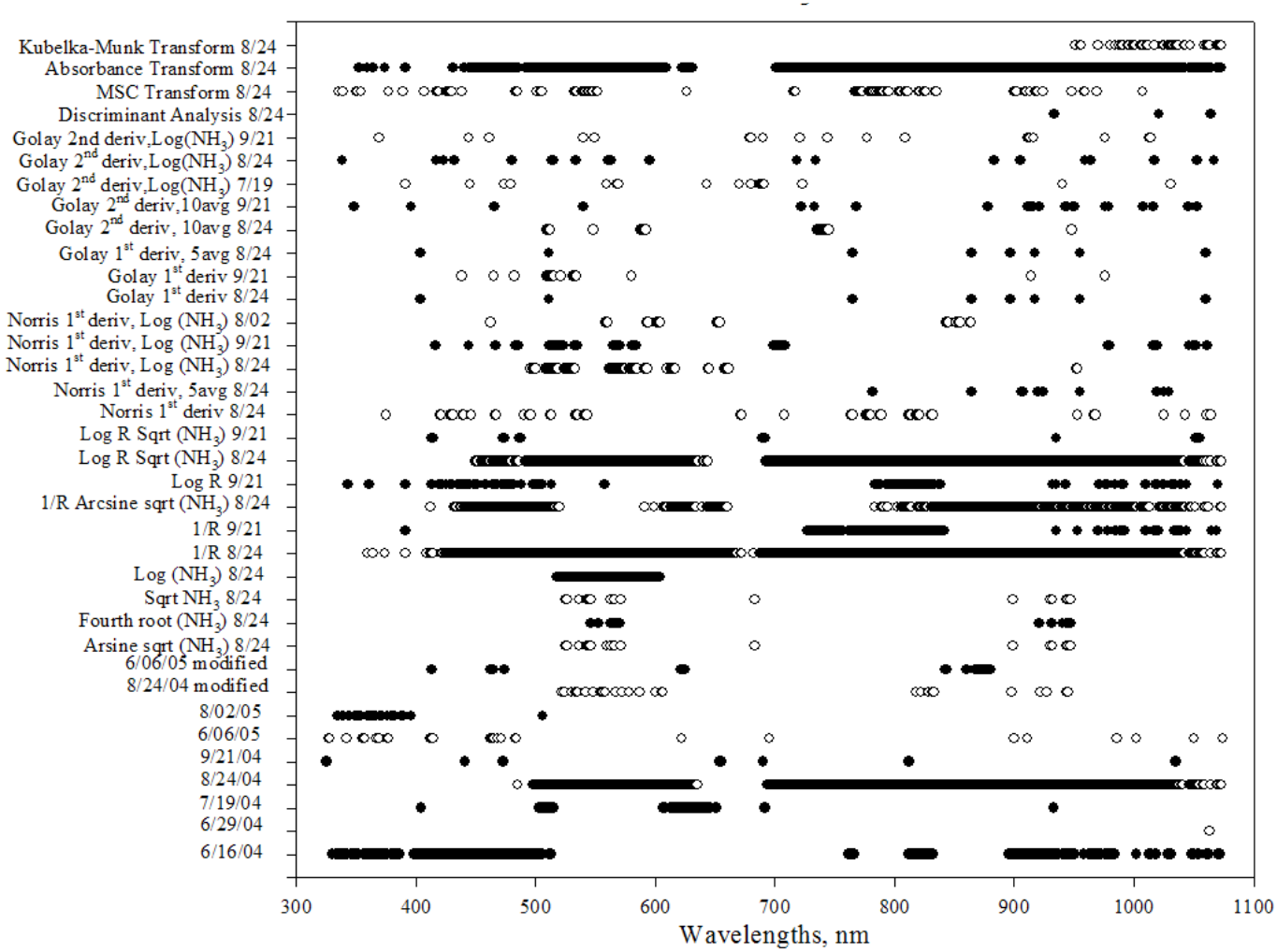



**Figure 3.4.5a. Significant spectral bands for $NH_3$ according to PLS-regressions at the two marsh sites.**

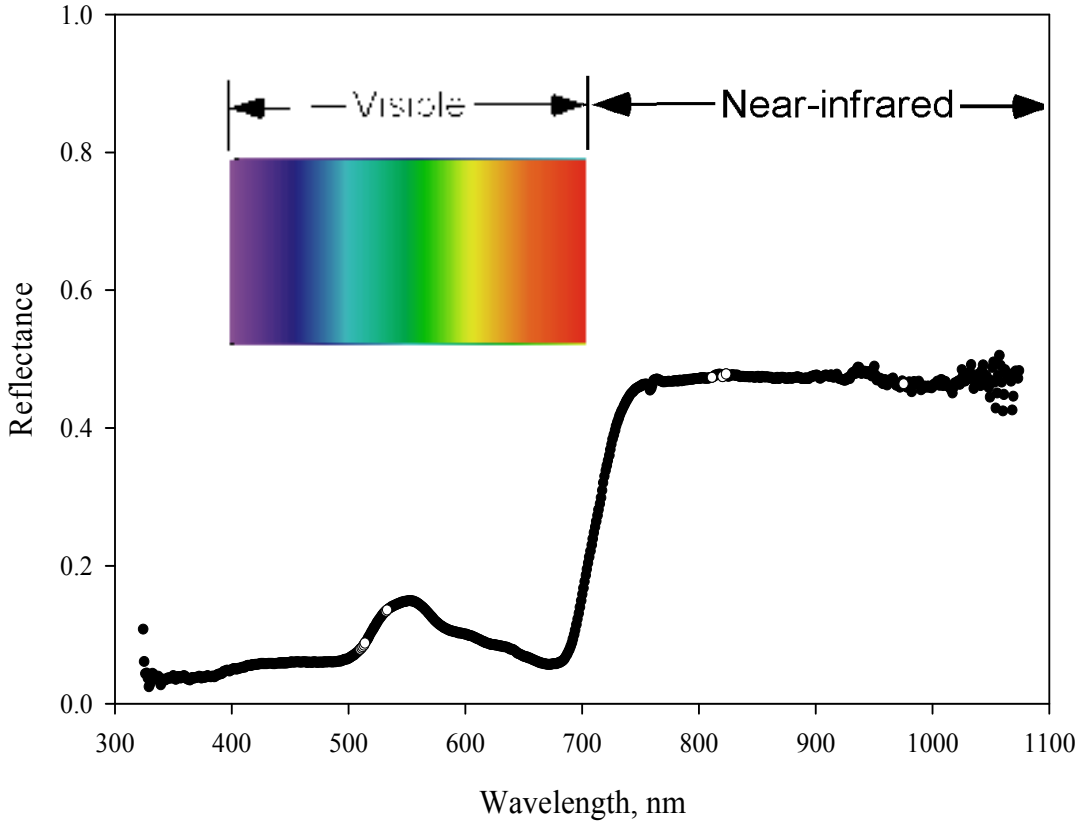



**Figure 3.4.5b. Spectral bands significant for ten or more $NH_3$ regressions at the two marsh sites are indicated by an open circle.**

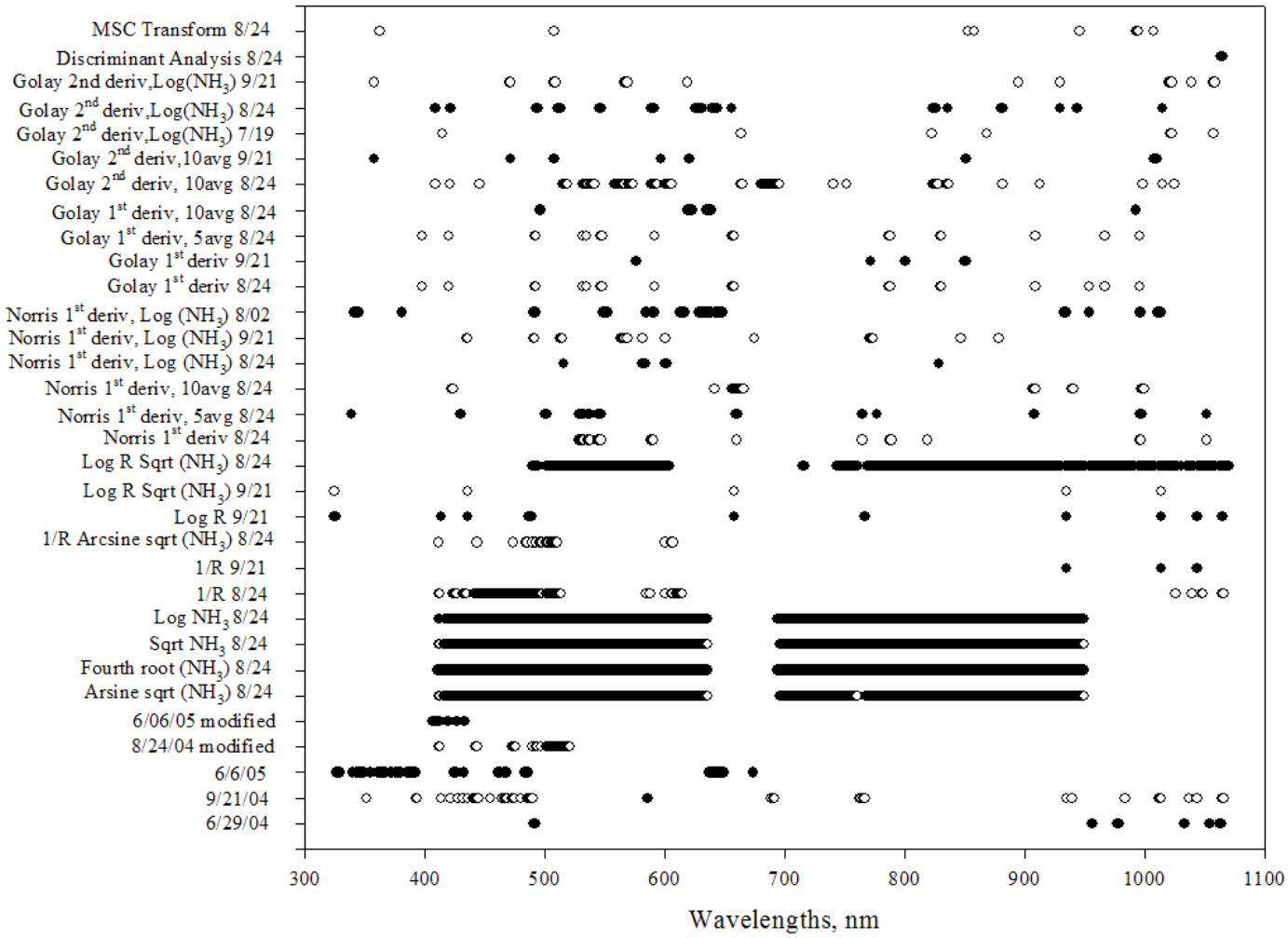



**Figure 3.4.6a. Significant spectral bands for $NH_3$ according to PLS-regressions at the *Phragmites*-absent site.**

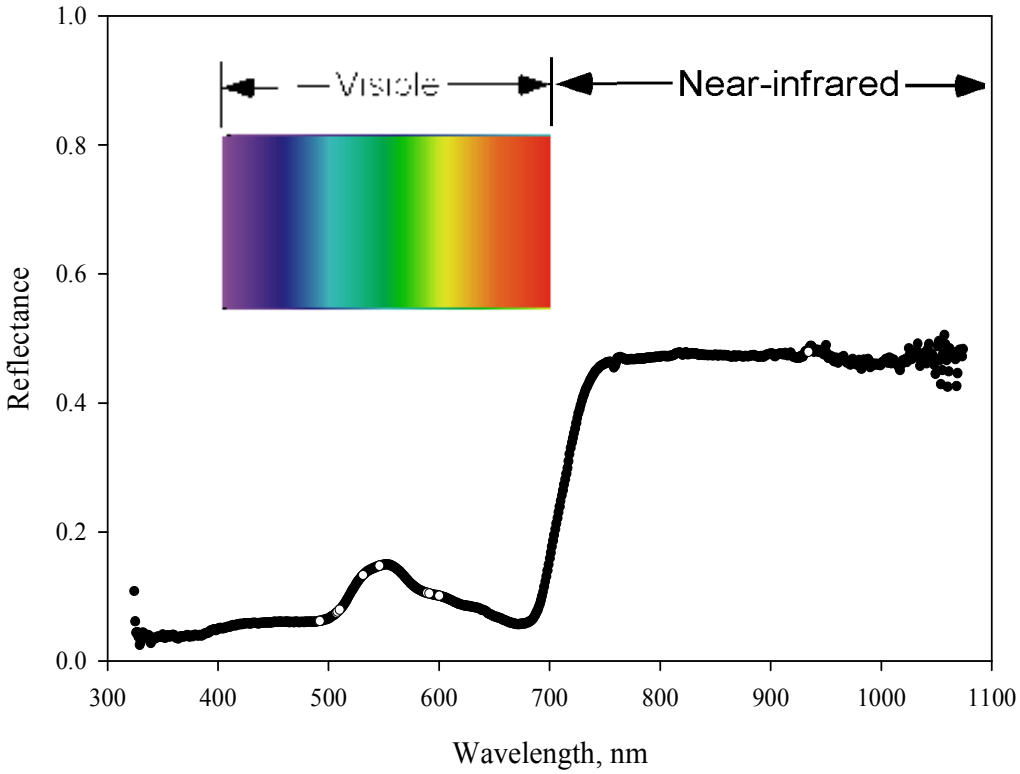



**Figure 3.4.6b. Spectral bands significant for ten or more $NH_3$regressions at the *Phragmites*-absent site are indicated by an open circle.**

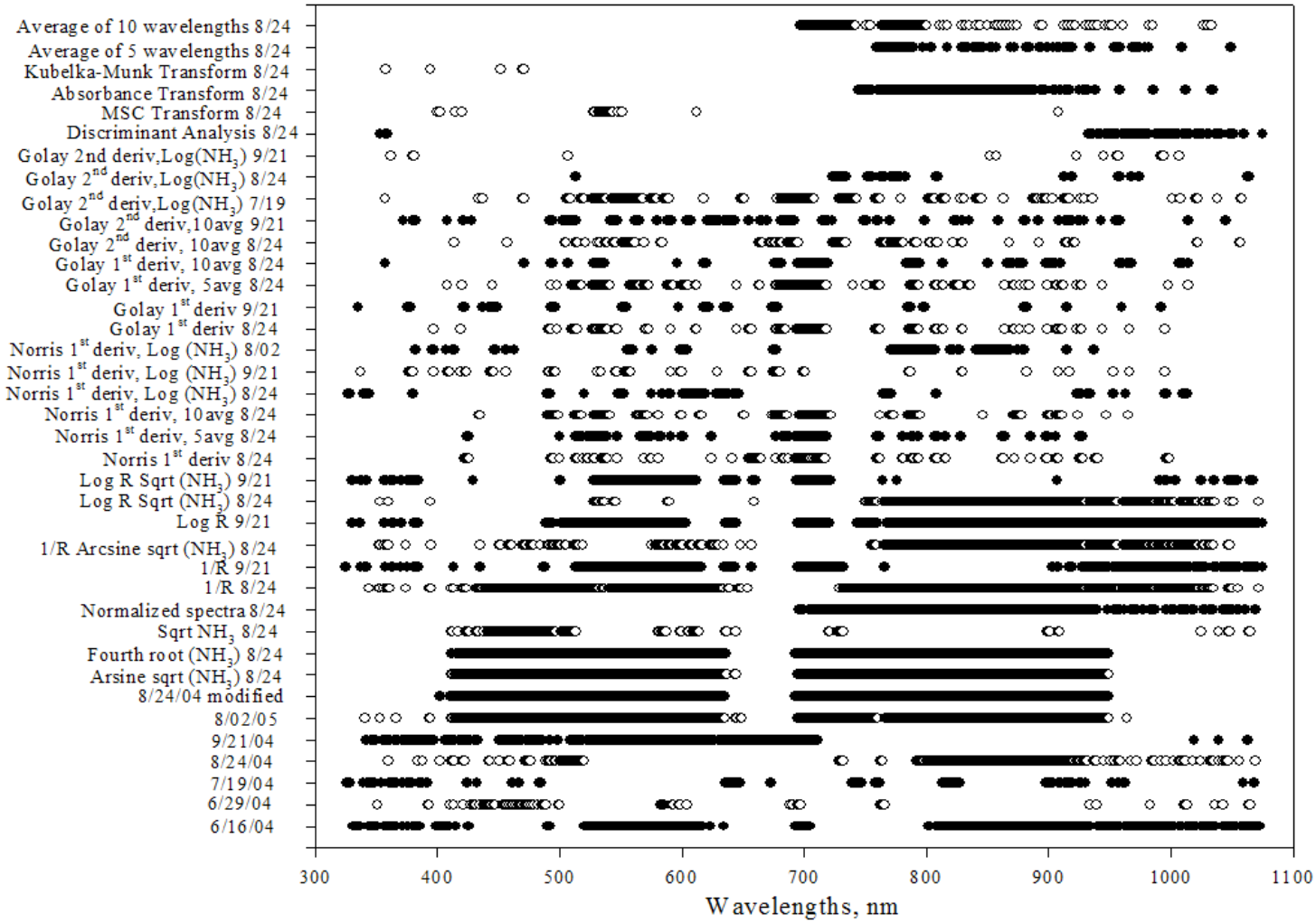



**Figure 3.4.7a. Significant spectral bands for $NH_3$ according to PLS-regressions at the *Phragmites*-dominant site.**

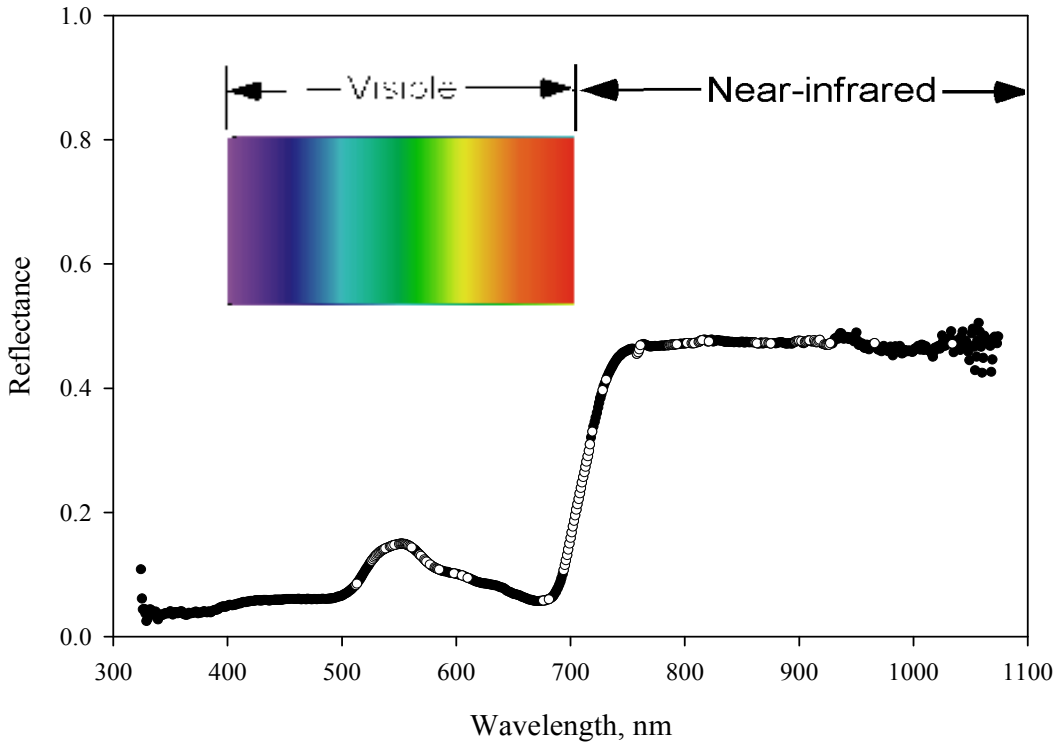



**Figure 3.4.7b. Spectral bands significant for ten or more $NH_3$ regressions at the *Phragmites*-dominant site are indicated by an open circle.**

*PLS Models of Nitrate*

PLS was able to quantify nitrate concentrations in sub-surface marsh water for the two sites during the end of the season (August and September). The best model predictive of nitrate used four untransformed spectral bands that were combined into two PLS-components with RMSEP of 1.5 and $R^2 = 0.67$ (Figure 3.4.8). Other models that quantified nitrate at the two marsh sites used the 1st or 2nd derivative of the spectra to reduce reflectance noise and the log of nitrate to normalize the sample distribution (Table 3.4.7).

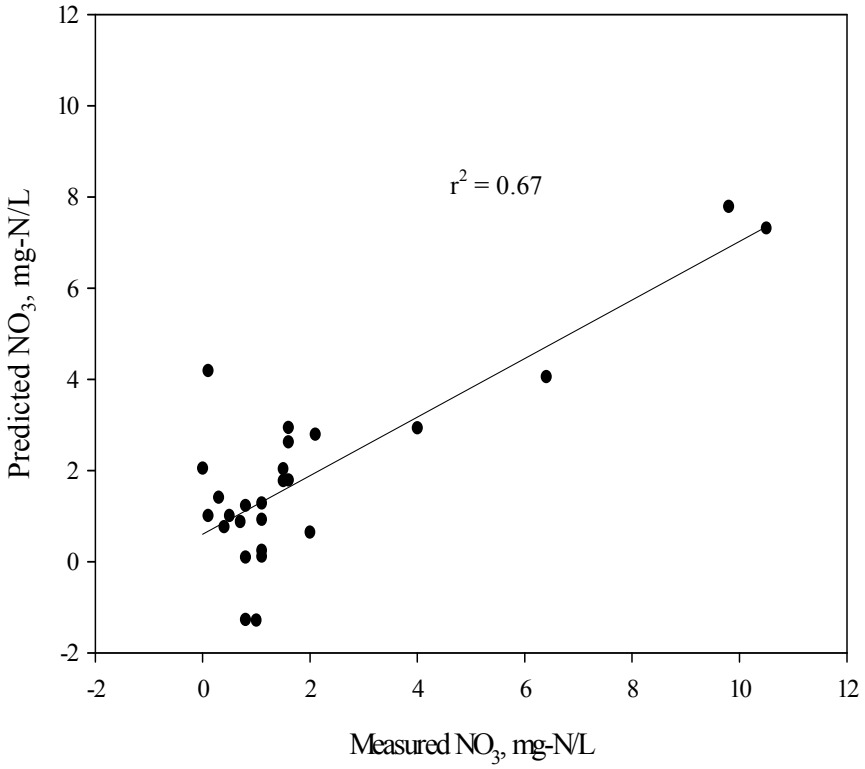



**Figure 3.4.8. Predicted vs measured nitrate PLS-regression for combined sites using four spectral bands of untransformed data from 8/02/05 to form two PLS-components with r = 0.82, RMSEP = 1.50.**

**Table 3.4.7. PLS-regression for nitrate at combined *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.82 | 1.50 | 26 | PD 3,6,10; PA12 | 2 | 4 | PD 3,6,10; PA12 missing NO3 data |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.02.05 | 0.80 | 0.30 | 26 | PD 3,6,10; PA12 | 2 | 41 | PD 3,6,10; PA12 missing NO3 data |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 9.21.04 | 0.73 | 0.21 | 30 | none | 1 | 26 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.71 | 0.69 | 30 | none | 2 | 28 | none |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.60 | 0.79 | 10 | none | 2 | none | Remainder used in calibration |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.60 | 0.87 | 30 | none | 2 | 30 | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.60 | 0.86 | 30 | none | 1 | 7 | none |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.57 | 0.88 | 30 | none | 1 | 18 | none |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.57 | 0.88 | 30 | none | 2 | 39 | none |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.57 | 0.88 | 30 | none | 2 | 39 | none |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.56 | 0.74 | 28 | PA2,5 | 8 | 9 | PA2,5 missing NO3 data |
| **Transform 1/R** | **none** | 8.24.04 | 0.54 | 0.91 | 30 | none | 1 | 219 | none |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.54 | 0.90 | 30 | none | 1 | 216 | none |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.52 | 0.93 | 30 | none | 2 | 51 | none |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.51 | 0.95 | 29 | PD6 | 3 | 26 | PD6 high reflectance |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 7.19.04 | 0.49 | 0.24 | 29 | PA2 | 1 | 83 | PA2 low NO3 conc. |
| **Truncated spectra (400-950nm)** | **Log $NO_3$** | 8.24.04 | 0.49 | 0.32 | 29 | PD6 | 8 | 71 | PD6 high reflectance |
| **Truncated spectra (400-950nm)** | **Sqrt $NO_3$** | 8.24.04 | 0.45 | 0.37 | 29 | PD6 | 2 | 7 | PD6 high reflectance |

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.44 | 1.00 | 29 | PD6 | 4 | 38 | PD6 high reflectance |
| **Log R** | **Sqrt $NO_3$** | 8.24.04 | 0.44 | 0.37 | 30 | none | 5 | 139 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.44 | 0.97 | 30 | none | 1 | 271 | none |
| **Log R** | **Sqrt $NO_3$** | 9.21.04 | 0.44 | 0.34 | 29 | PA8 | 2 | 31 | PA8 noisy reflectance |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.42 | 0.04 | 29 | PD6 | 3 | 4 | PD6 high reflectance |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.42 | 1.35 | 10 | none | 1 | none | Remainder used in calibration |
| **Transform 1/R** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.42 | 0.04 | 30 | none | 1 | 308 | none |
| **Truncated spectra (400-950nm)** | **4th root $NO_3$** | 8.24.04 | 0.39 | 0.18 | 29 | PD6 | 2 | 7 | PD6 high reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.39 | 1.00 | 30 | none | 1 | 41 | none |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 8.24.04 | 0.37 | 0.28 | 29 | PD1 | 1 | 45 | PD1 low NO3 conc. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.36 | 0.63 | 29 | PD3 | 2 | 30 | PD3 high NO3 concentration |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.33 | 1.02 | 30 | none | 1 | 512 | none |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.24.04 | 0.33 | 0.34 | 30 | none | 3 | 12 | none |
| **MSC Transformation** | **none** | 8.24.04 | 0.32 | 1.07 | 30 | none | 7 | none | none |
| **Norris 1st Derivative** | **Log $NO_3$** | 9.21.04 | 0.24 | 0.31 | 30 | none | 2 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.21 | 2.31 | 27 | PD14; PA 12,15 | 2 | 60 | PD4; PA 12,15 missing NO3 data |
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | 0.12 | 2.35 | 27 | PD4; PA 12,15 | 1 | none | PD4; PA 12,15 missing NO3 data |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | -0.17 | 0.96 | 26 | PD 3,12,14; PA2 | 1 | none | PD 3,12,14; PA2 missing NO3 data |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.27 | 1.04 | 30 | none | 1 | none | none |
| **Transform 1/R** | **none** | 9.21.04 | -0.27 | 1.03 | 30 | none | 1 | 56 | none |
| **Log R** | **none** | 9.21.04 | -0.27 | 1.04 | 30 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | -0.32 | 2.07 | 30 | none | 1 | none | none |

**Table 3.4.8. PLS-regression transformations tested on nitrate concentrations at the two marsh sites.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NO_3$) | Truncated, 4th root $NO_3$ | Truncated Sqrt ($NO_3$) | Truncated $Log_{10}$ $NO_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NO_3$) | Log R | Log R, Sqrt ($NO_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NO_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NO_3$) | Excluding $NO_3 > 2$ | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | | |

PLS was very successful in predicting nitrate at the *Phragmites*-dominant site, particularly during August and September of both years. The best PLS model at the *Phragmites*-dominant site used the same untransformed data (8/02/05) that was used in the best model for the two marsh sites. At the *Phragmites*-dominant site, the PLS model used 40 spectral bands to form seven PLS-components with RMSEP of 1.08 and $R^2 = 0.90$ (Figure 3.4.9).

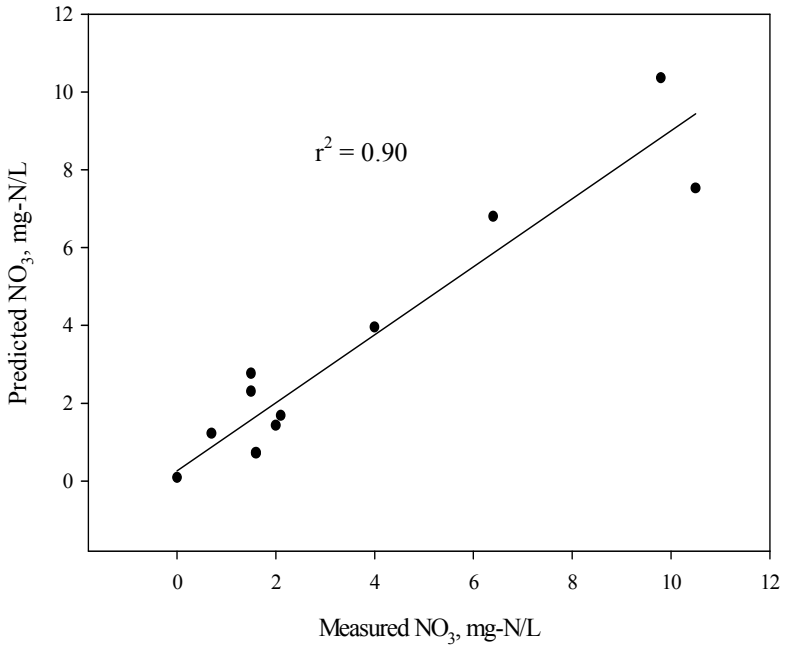



**Figure 3.4.9. Predicted vs measured nitrate PLS-regression at the *Phragmites*-dominant site. Seven PLS-components were formed from 40 spectral bands of untransformed reflectance data from 8/02/05 with r=0.95 and RMSEP=1.08.**

The 1st and 2nd derivatives were also used in models predictive of nitrate sub-surface concentrations at the *Phragmites*-dominant site. On 9/21/04, a PLS model using 75 spectral bands of the 1st derivative transformed reflectance yielded an RMSEP of 0.40 and $R^2 = 0.88$ (Figure 3.4.10).

Among the transformations yielding the best regressions at the *Phragmites*-dominant site were the 1st and 2nd derivatives of the reflectance curve, and the log of nitrate concentration (Table 3.4.9). Since several reflectance and nitrate transformations were used in the PLS-regressions, a complete summary of transformations performed on the *Phragmites*-dominant site data is given in Table 3.4.10.

At the *Phragmites*-absent site, nitrate was predicted correctly using PLS during August and September. During the end of the 2004 growing season, nitrate concentrations were, on average, between 1-2 mg-N/L at the *Phragmites*-absent site. PLS-regression was able to quantify this range using transformed (1st and 2nd derivative, inverse reflectance, normalized) spectra (Table 3.4.11). The best PLS model for the *Phragmites*-absent site used the log of nitrate and 75 spectral bands of 1st derivative transformed reflectance that established three PLS-components with RMSEP of 0.11 and $R^2$ of 0.81 (Figure 3.4.11). When the inverse reflectance of sample date 8/24/04 was used, PLS correctly predicted nitrate concentrations using 234 spectral bands of inverse reflectance, primarily in the near-infrared, to form six PLS-components with an RMSEP of 0.15 and $R^2$ of 0.79 (Figure 3.4.12).

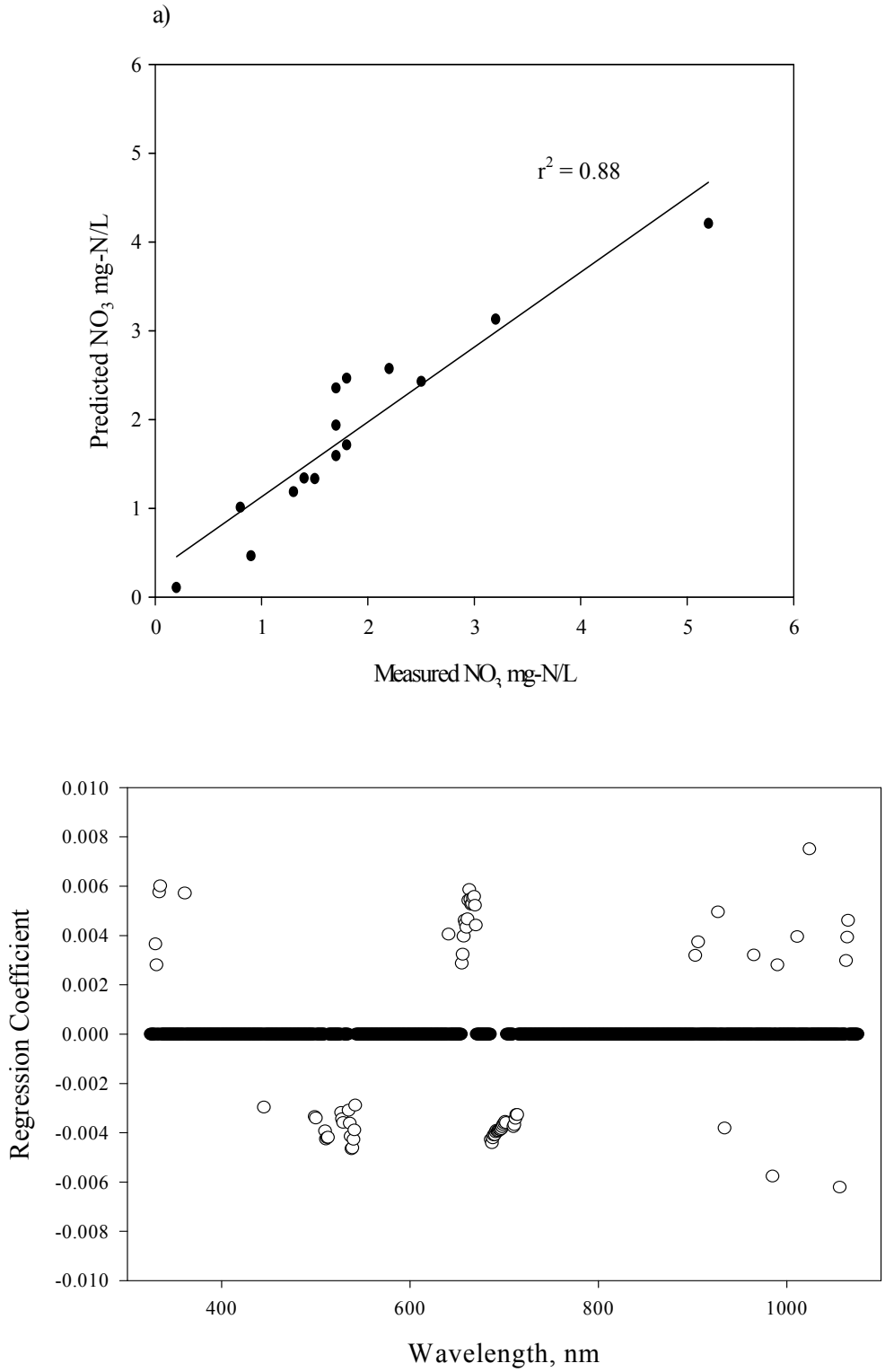



**Figure 3.4.10. (a) Predicted vs measured nitrate PLS-regression at the *Phragmites*-dominant site using 75 spectral bands of the 1st derivative of the spectrum (9/21/04) to form seven PLS-components with r = 0.94 and RMSEP of 0.40. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

**Table 3.4.9. PLS-regression for nitrate at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.95 | 1.08 | 12 | Plots 3,6,10 | 7 | 40 | Plots 3,6,10 missing $NO_3$ data |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.94 | 0.40 | 15 | none | 7 | 75 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.93 | 0.42 | 15 | none | 2 | 35 | none |
| **Norris 1st Derivative** | **Log $NO_3$** | 9.21.04 | 0.88 | 0.09 | 14 | Plot 1 | 5 | 49 | Plot 1 low $NO_3$ conc |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.02.05 | 0.76 | 0.24 | 11 | Plots 3,6,9,10 | 1 | 43 | Plots 3,6,10 missing $NO_3$; Plot 9 low $NO_3$ |
| **Transform 1/R** | **none** | 9.21.04 | 0.69 | 0.83 | 15 | none | 10 | 19 | none |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 9.21.04 | 0.67 | 0.23 | 15 | none | 1 | 10 | none |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.60 | 1.07 | 14 | Plot 6 | 1 | 153 | Plot 6 high reflectance |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.58 | 1.10 | 14 | Plot 6 | 1 | 130 | Plot 6 high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.57 | 1.10 | 14 | Plot 6 | 1 | 138 | Plot 6 high reflectance |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.57 | 1.10 | 14 | Plot 6 | 1 | 86 | Plot 6 high reflectance |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.56 | 2.21 | 5 | none | 1 | none | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.53 | 1.12 | 14 | Plot 6 | 1 | 99 | Plot 6 high reflectance |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.24.04 | 0.53 | 0.18 | 13 | Plots 1,6 | 1 | 88 | Plot 1 low $NO_3$ conc; Plot 6 high reflect. |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 7.19.04 | 0.50 | 0.31 | 15 | none | 1 | 15 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.49 | 1.12 | 15 | none | 1 | 31 | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.48 | 1.16 | 14 | Plot 6 | 1 | 120 | Plot 6 high reflectance |
| **Golay 2nd Derivative, avg 10** | **Log $NO_3$** | 8.24.04 | 0.47 | 0.15 | 13 | Plots 1,3 | 1 | 4 | Plot 1 low $NO_3$ conc; Plot 3 high $NO_3$ |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.46 | 1.26 | 14 | Plot 6 | 3 | 171 | Plot 6 high reflectance |

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | 0.45 | 1.45 | 12 | Plots 6,12,14 | 4 | 60 | Plots 6,12 high $NO_3$; Plot 14 missing $NO_3$ |
| **MSC Transformation** | **none** | 8.24.04 | 0.35 | 1.19 | 15 | none | 1 | 64 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.35 | 1.24 | 14 | Plot 6 | 1 | 141 | Plot 6 high reflectance |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.33 | 1.25 | 14 | Plot 6 | 1 | 149 | Plot 6 high reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.32 | 1.25 | 14 | Plot 6 | 1 | 108 | Plot 6 high reflectance |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.28 | 1.32 | 14 | Plot 6 | 1 | 123 | Plot 6 high reflectance |
| **Transform 1/R** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.28 | 0.05 | 14 | Plot 6 | 1 | 85 | Plot 6 high reflectance |
| **Log R** | **Sqrt $NO_3$** | 8.24.04 | 0.27 | 0.46 | 14 | Plot 6 | 1 | 136 | Plot 6 high reflectance |
| **Truncated spectra (400-950nm)** | **4th root $NO_3$** | 8.24.04 | 0.26 | 0.23 | 13 | Plots 6,15 | 1 | 104 | Plots 6,15 high reflect |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.24 | 0.05 | 14 | Plot 6 | 1 | 105 | Plot 6 high reflectance |
| **Truncated spectra (400-950nm)** | **Sqrt $NO_3$** | 8.24.04 | 0.24 | 0.48 | 14 | Plot 6 | 1 | 104 | Plot 6 high reflectance |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.21 | 2.60 | 5 | none | 1 | none | none |
| **Truncated spectra (400-950nm)** | **Log $NO_3$** | 8.24.04 | 0.19 | 0.42 | 13 | Plots 6,15 | 1 | 79 | Plots 6,15 high reflect |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.17 | 1.22 | 14 | Plot 2 | 1 | 21 | Plot 2 high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.16 | 0.71 | 15 | none | 1 | 236 | none |
| **Log R** | **none** | 9.21.04 | 0.11 | 1.22 | 14 | Plot 2 | 1 | 4 | Plot 2 high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.04 | 1.86 | 13 | Plots 6,14 | 1 | 224 | Plot 6 high $NO_3$; Plot 14 missing $NO_3$ |
| **Log R** | **Sqrt $NO_3$** | 9.21.04 | 0.03 | 0.43 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | -0.27 | 2.64 | 15 | none | 1 | none | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | -0.53 | 1.70 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | -0.75 | 1.26 | 12 | Plots 3,12,14 | 1 | none | Plots 3,12,14 missing $NO_3$ data |

**Table 3.4.10. PLS-regression transformations tested on nitrate concentrations at the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NO_3$) | Truncated, 4th root $NO_3$ | Truncated Sqrt ($NO_3$) | Truncated $Log_{10}$ $NO_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NO_3$) | Log R | Log R, Sqrt ($NO_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NO_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NO_3$) | Excluding $NO_3 > 2$ | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | |

**Table 3.4.11. PLS-regression for nitrate concentration at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **Log $NO_3$** | 9.21.04 | 0.90 | 0.11 | 14 | Plot 10 | 3 | 75 | Plot 10 high $NO_3$ conc |
| **Transform 1/R** | **none** | 8.24.04 | 0.89 | 0.15 | 15 | none | 6 | 234 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.88 | 0.16 | 15 | none | 6 | 247 | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.86 | 0.17 | 14 | Plot 1 | 10 | 11 | Plot 1 high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.83 | 0.18 | 15 | none | 5 | 182 | none |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.83 | 0.18 | 15 | none | 5 | 182 | none |
| **Golay 2nd Derivative** | **Log $NO_3$** | 8.24.04 | 0.83 | 0.06 | 14 | Plot 6 | 4 | 23 | Plot 6 low $NO_3$ conc. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.83 | 0.23 | 14 | Plot 10 | 2 | 25 | Plot 10 high $NO_3$ conc |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.79 | 0.20 | 15 | none | 3 | 181 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.77 | 0.21 | 15 | none | 1 | 3 | none |
| **Golay 2nd Derivative** | **Log $NO_3$** | 9.21.04 | 0.77 | 0.18 | 14 | Plot 10 | 3 | 17 | Plot 10 high $NO_3$ conc |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.02.05 | 0.76 | 0.24 | 14 | Plot 12 | 4 | 160 | Plot 12 missing $NO_3$ data |
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.76 | 0.21 | 15 | none | 9 | 206 | none |
| **Transform 1/R** | **none** | 9.21.04 | 0.76 | 0.27 | 13 | Plots 10,13 | 2 | 17 | Plot 10 high $NO_3$; Plot 13 low reflect. |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.75 | 0.38 | 12 | Plots 2,3,10 | 2 | 14 | Plot 2 missing $NO_3$; Plots 3,10 high $NO_3$ |
| **Norris 1st Derivative** | **Log $NO_3$** | 8.24.04 | 0.75 | 0.07 | 14 | Plot 6 | 3 | 134 | Plot 6 low $NO_3$ conc. |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.74 | 0.24 | 15 | none | 6 | 252 | none |
| **Golay 2nd Derivative** | **none** | 9.21.04 | 0.74 | 0.27 | 14 | Plot 10 | 1 | 16 | Plot 10 high $NO_3$ conc |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.73 | 0.22 | 15 | none | 2 | 3 | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.72 | 0.23 | 15 | none | 3 | 174 | none |

| Spectra Transformations | $NO_3$ Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **Sqrt $NO_3$** | 8.24.04 | 0.71 | 0.17 | 14 | Plot 1 | 8 | 191 | Plot 1 high reflectance |
| **Truncated spectra (400-950nm)** | **none** | 6.06.05 | 0.69 | 1.61 | 12 | Plots 3,12,15 | 4 | 13 | Plot 3 high reflect; Plots 12, 15 missing $NO_3$ |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.66 | 0.28 | 13 | Plots 11,12 | 1 | 23 | Plot 11 high $NO_3$ conc; Plot 12 missing $NO_3$ |
| **Transform 1/R** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.60 | 0.02 | 15 | none | 2 | 14 | none |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.60 | 0.33 | 14 | Plot 10 | 3 | 5 | Plot 10 high $NO_3$ conc |
| **Golay 2nd Derivative** | **Log $NO_3$** | 7.19.04 | 0.57 | 0.16 | 14 | Plot 2 | 2 | 11 | Plot 2 low $NO_3$ conc |
| **MSC Transformation** | **none** | 8.24.04 | 0.56 | 0.28 | 15 | none | 2 | 37 | none |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.56 | 0.35 | 14 | Plot 10 | 3 | 167 | Plot 10 high $NO_3$ conc |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.53 | 0.78 | 13 | Plots 2, 5 | 2 | 12 | Plots 2,5 missing $NO_3$ data |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.53 | 0.31 | 10 | none | 1 | none | Remainder used in calibration |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.51 | 0.39 | 14 | Plot 2 | 1 | 462 | Plot 2 low $NO_3$ conc |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.51 | 0.31 | 14 | Plot 1 | 3 | 229 | Plot 1 high reflectance |
| **Log R** | **Sqrt $NO_3$** | 9.21.04 | 0.51 | 0.22 | 14 | Plot 10 | 3 | 52 | Plot 10 high $NO_3$ conc |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.50 | 0.42 | 10 | none | 1 | none | Remainder used in calibration |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt ($NO_3$)** | 8.24.04 | 0.43 | 0.02 | 14 | Plot 1 | 6 | none | Plot 1 high reflectance |
| **Truncated spectra (400-950nm)** | **4th root $NO_3$** | 8.24.04 | 0.37 | 0.12 | 14 | Plot 1 | 6 | none | Plot 1 high reflectance |
| **Truncated spectra (400-950nm)** | **Sqrt $NO_3$** | 8.24.04 | 0.31 | 0.21 | 15 | none | 2 | none | none |
| **Truncated spectra (400-950nm)** | **Log $NO_3$** | 8.24.04 | 0.20 | 0.29 | 15 | none | 2 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | -0.06 | 2.52 | 12 | Plots 3,12,15 | 1 | none | Plot 3 high reflect; Plots 12, 15 missing $NO_3$ |
| **Log R** | **none** | 9.21.04 | -0.31 | 0.59 | 14 | Plots 10 | 1 | none | Plot 10 high $NO_3$ conc |

**Table 3.4.12. PLS-regression transformations tested on nitrate concentrations at the *Phragmites*-absent site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt ($NO_3$) | Truncated, 4th root $NO_3$ | Truncated Sqrt ($NO_3$) | Truncated $Log_{10}$ $NO_3$ | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt ($NO_3$) | Log R | Log R, Sqrt ($NO_3$) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | X | | | | | | | | X | | X | X | |
| 6/6/2005 | X | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Deriv, Log ($NO_3$) | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log ($NO_3$) | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | | X | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | |
| 6/6/2005 | | | | | | | | | | | | | | | |
| 8/2/2005 | | | | X | | | | | | | | | | | |

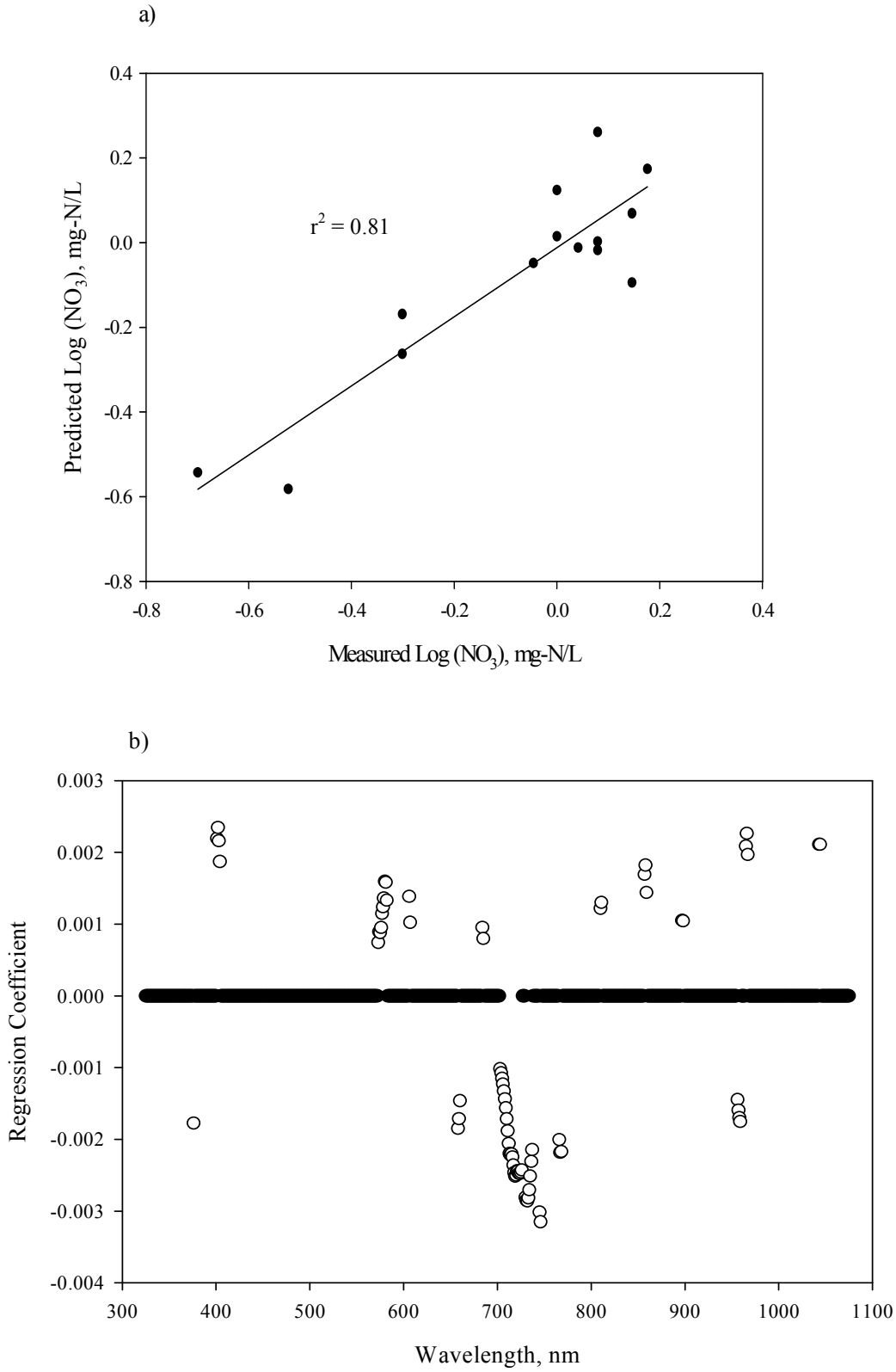
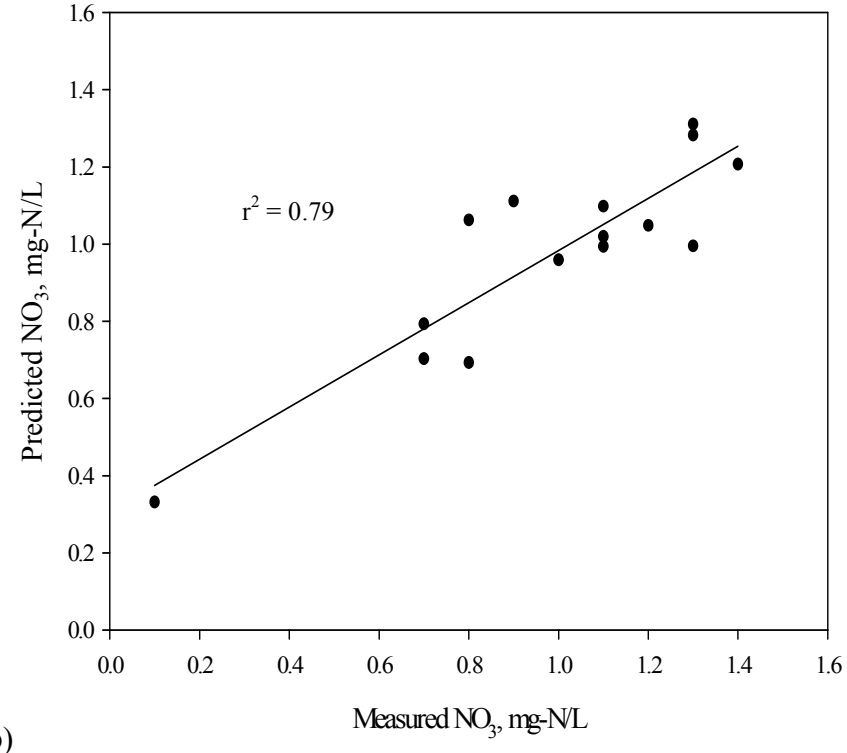



**Figure 3.4.11. (a) Predicted vs measured log of nitrate PLS-regression at the *Phragmites*-absent site which used 75 spectral bands of the 1st derivative of the 9/21/04 reflectance to form three PLS-components with r = 0.90 and RMSEP of 0.11. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

a)




b)

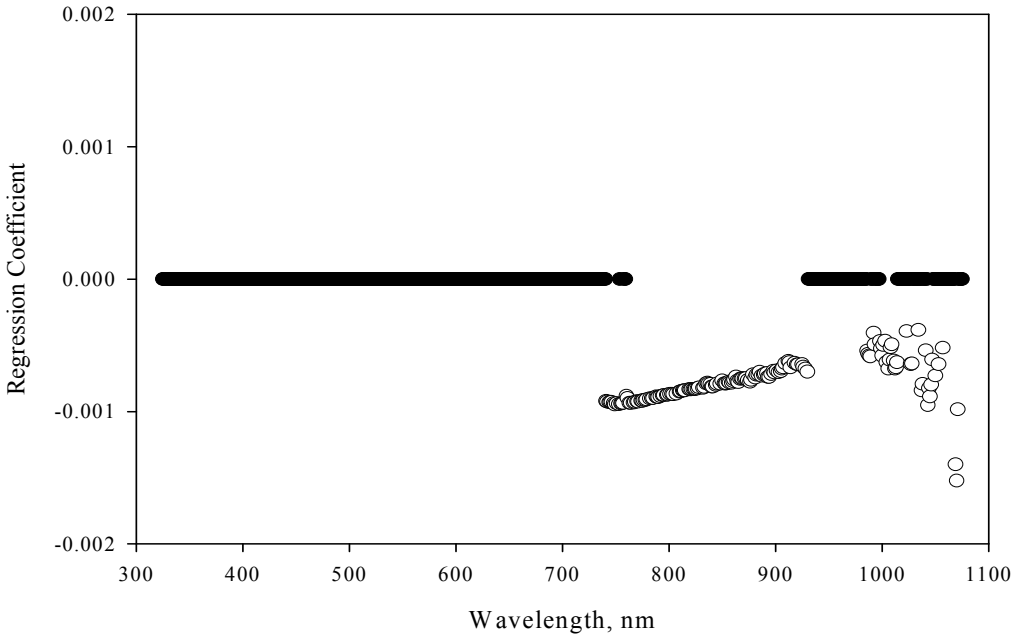



**Figure 3.4.12. (a) Predicted vs measured nitrate PLS-regression of the *Phragmites*-absent site which used 234 spectral bands of the inverse reflectance from 8/24/04 to form six PLS-components with r = 0.89 and RMSEP of 0.15. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

Spectral bands used in the PLS models for the two marsh sites, the *Phragmites*-dominant site, and the *Phragmites*-absent site were examined for reflectance trends. A summary of spectral bands used in PLS models at the two marsh sites shows that several regressions used bands in the visible green, red-edge, and near-infrared (Figure 3.4.13a). Ten or more regressions used only spectral bands in the green (530-590 nm) (Figure 3.4.13b).

At the *Phragmites*-dominant site, many regressions had significant spectral bands in throughout the visible and near-infrared, but only bands in the blue and green range (500-600 nm) were significant for ten or more regressions (Figure 3.4.14).

For the *Phragmites*-absent site, regressions used several spectral bands between 500-600 nm, as well as the red-edge (700-720nm), but the spectral bands used in ten or more regressions included only the red-edge spectral bands and a few spectral bands in the blue and green wavebands (Figure 3.4.15). A list of the illustrated bands, significant to ten or more regressions for both sites, can be found in the Appendix.

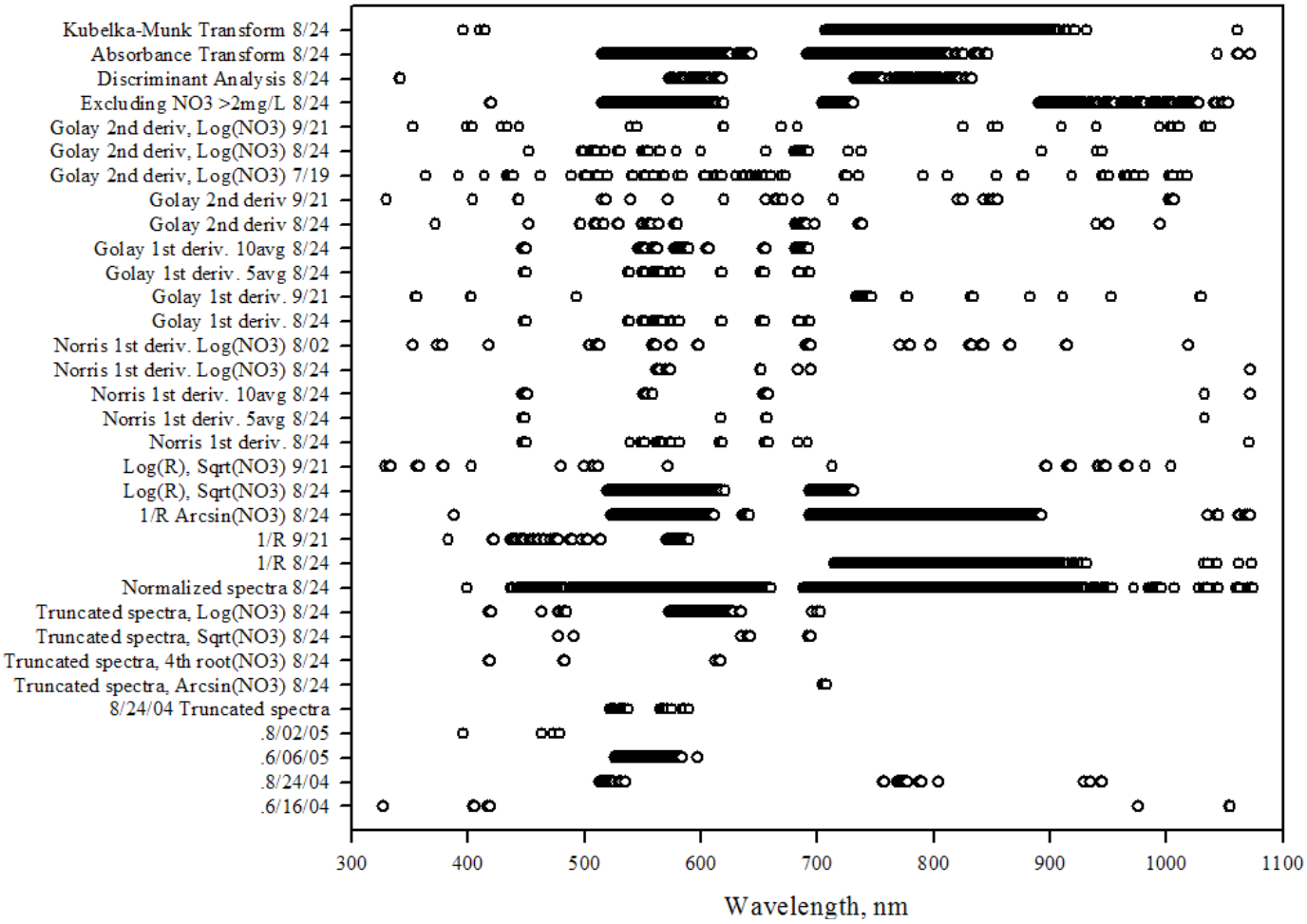



**Figure 3.4.13a. Significant spectral bands for $NO_3$ according to PLS-regressions at the two marsh sites.**

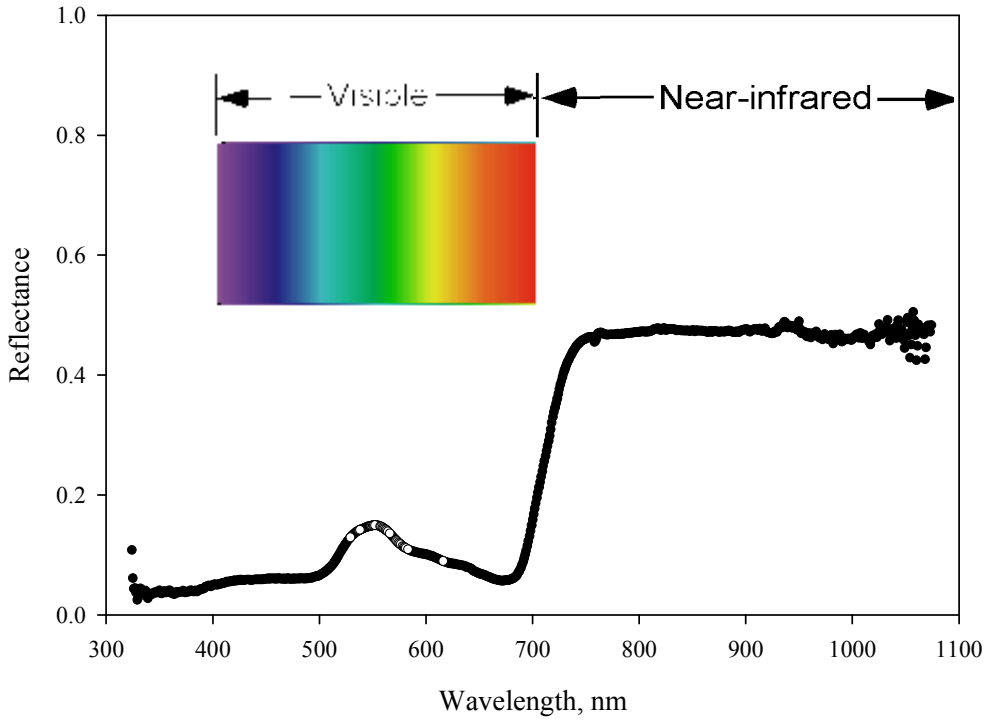



**Figure 3.4.13b. Spectral bands significant for ten or more nitrate regressions at the two marsh sites are indicated by an open circle.**

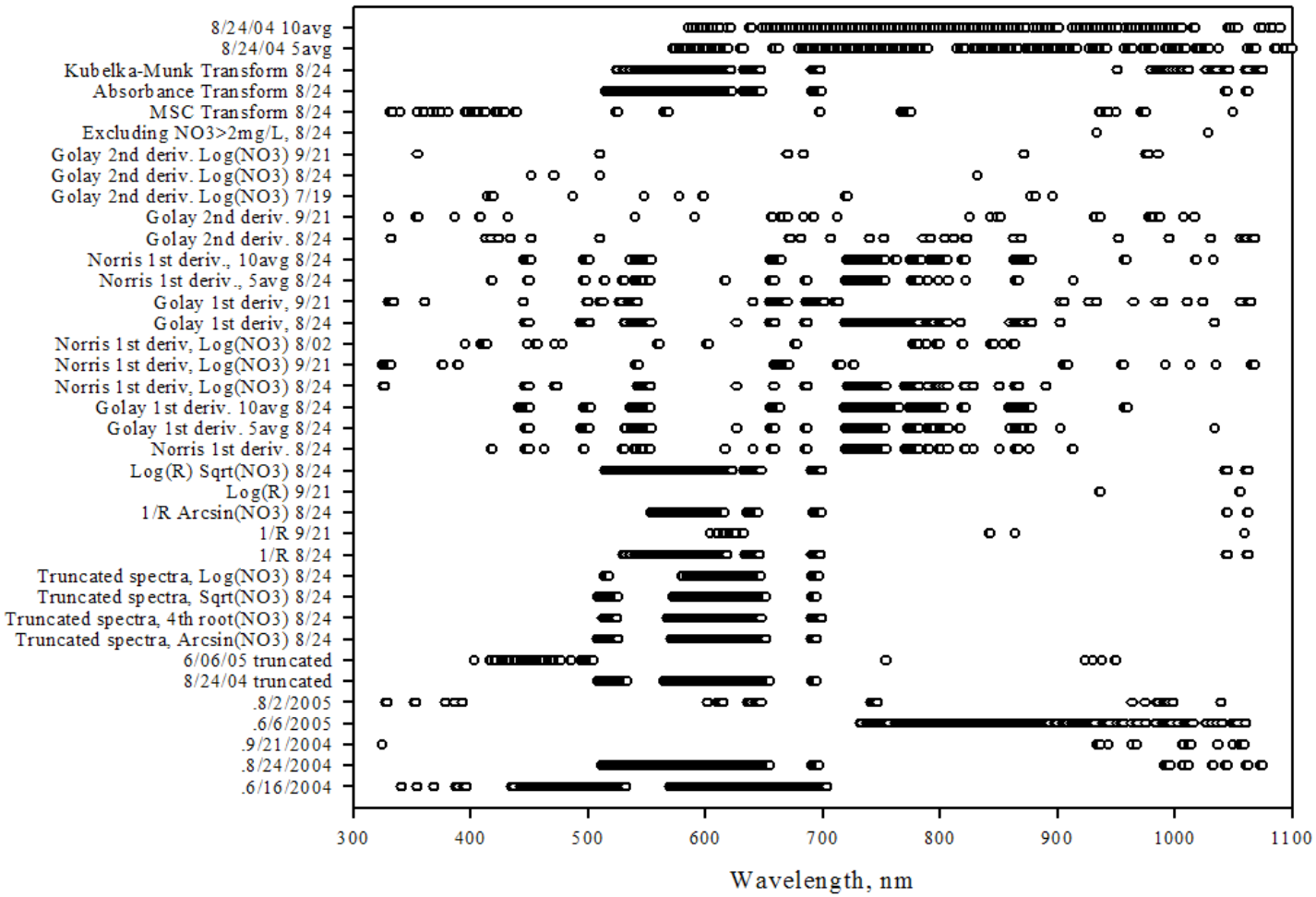



**Figure 3.4.14a. Significant spectral bands for $NO_3$ according to PLS-regressions at the *Phragmites*-dominant site.**

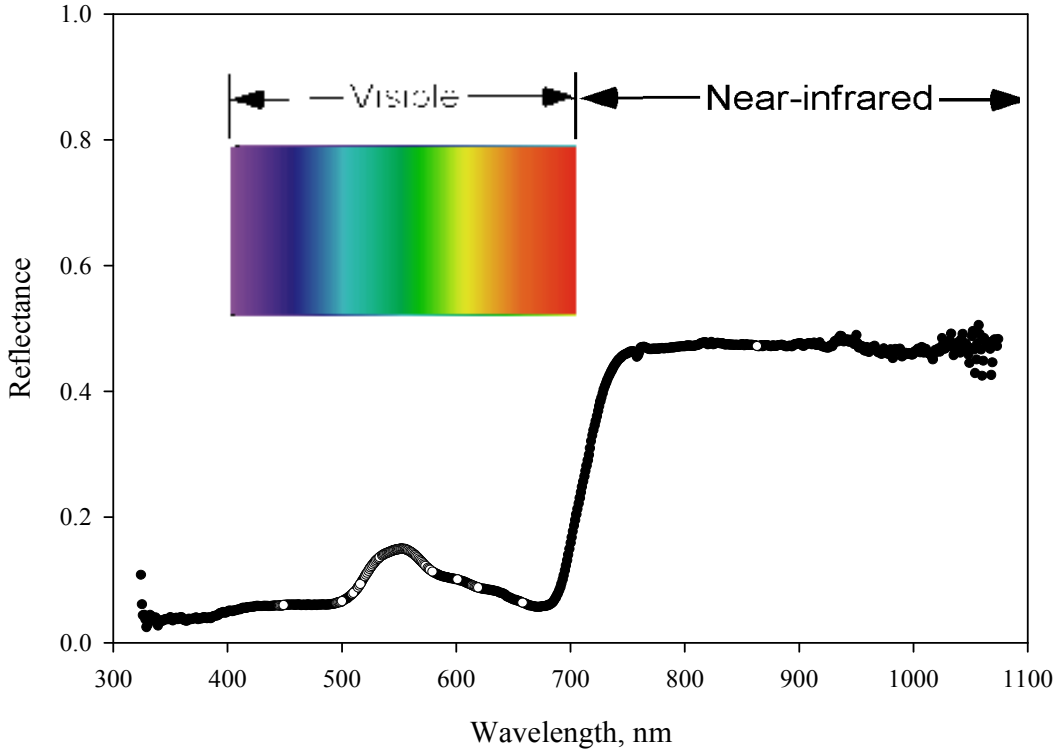



**Figure 3.4.14b. Spectral bands significant for ten or more regressions for nitrate at the *Phragmites*-dominant site are indicated by an open circle.**

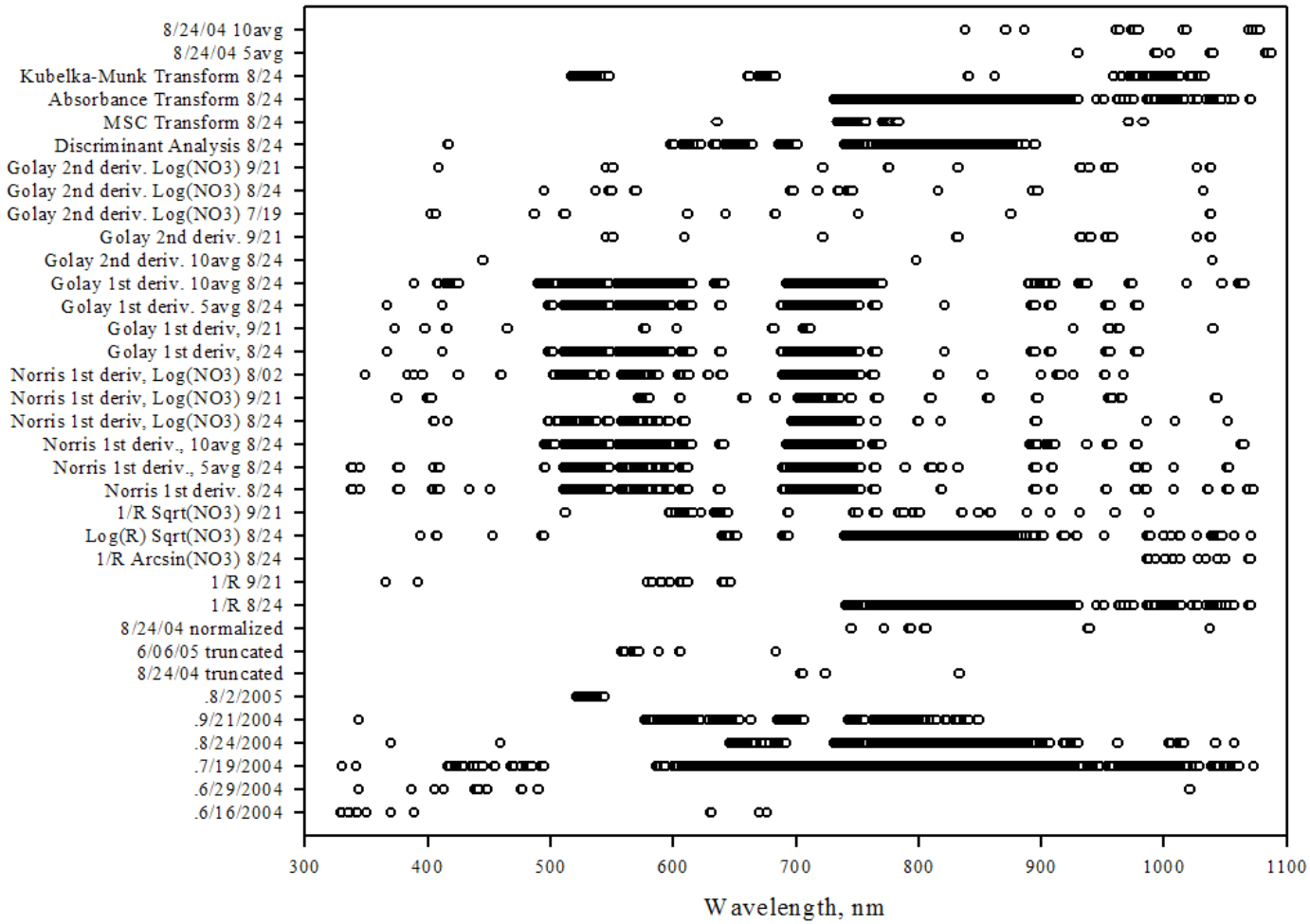



**Figure 3.4.15a. Significant spectral bands for $NO_3$ according to PLS-regressions at the *Phragmites*-absent site.**

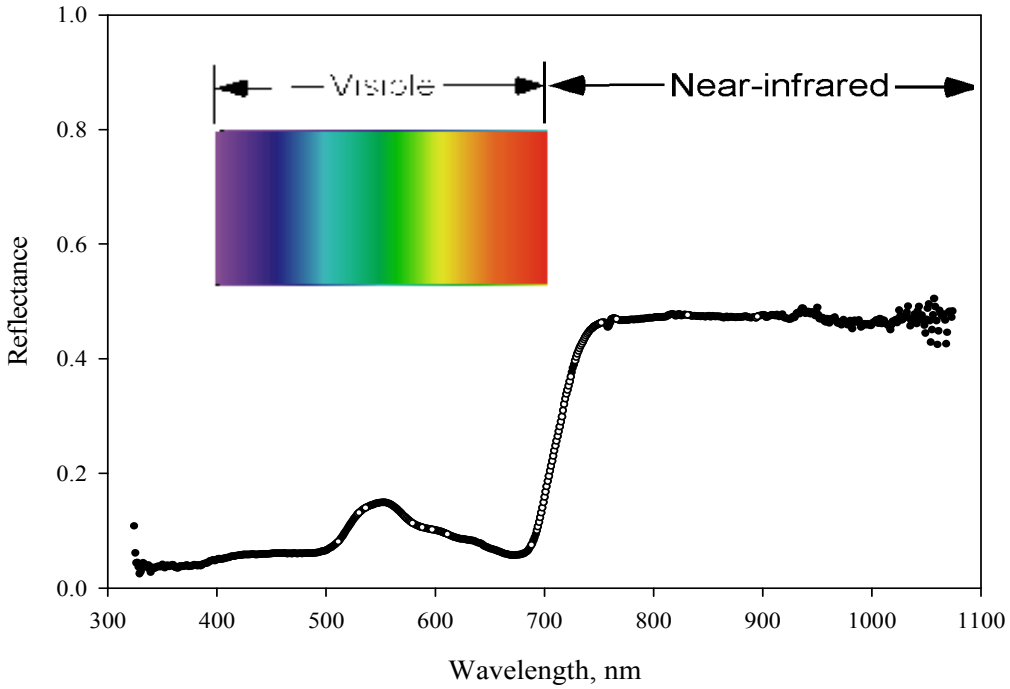



**Figure 3.4.15b. Spectral bands significant for ten or more regressions for nitrate at the *Phragmites*-absent site are indicated by an open circle.**

*PLS Models of Total Nitrogen*

Spectroradiometric PLS models were able to predict total nitrogen concentrations in sub-surface marsh water at both the *Phragmites*-dominant and *Phragmites*-absent sites. Models at both sites used transformations of the canopy reflectance (1st and 2nd derivatives) and nitrogen concentration (Log) to quantify nitrogen concentrations during July and August (Tables 3.4.13 and 3.4.15). At the *Phragmites*-dominant site, the highest correlated model used the log of nitrogen concentration on 6/29/04 and 33 spectral bands of 1st derivative transformed reflectance to form three PLS-components with RMSEP of 0.09 and $R^2 = 0.88$ (Figure 3.4.16). Log nitrogen concentrations were uniformly distributed and had discrete values due to the Hach Digestion procedure used to analyze total Kjeldahl nitrogen.

**Table 3.4.13. PLS-regression for total nitrogen at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | TKN Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | Number of sig. spectral bands | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Norris 1st Derivative | Log TKN | 6.29.04 | 0.94 | 0.09 | 12 | Plots 1,4,12 | 3 | 33 | Plots 4,12 missing TKN; Plot 1 high TKN |
| Norris 1st Derivative | none | 7.19.04 | 0.93 | 2.82 | 14 | Plot 5 | 5 | 28 | Plot 5 high reflectance |
| Norris 1st Derivative | Log TKN | 7.19.04 | 0.93 | 0.10 | 14 | Plot 5 | 6 | 34 | Plot 5 high reflectance |
| Golay 2nd Derivative, avg 10 | Log TKN | 6.29.04 | 0.91 | 0.11 | 12 | Plots 1,4,12 | 1 | 31 | Plots 4,12 missing TKN; Plot 1 high TKN |
| Golay 2nd Derivative, avg 10 | none | 6.29.04 | 0.88 | 3.27 | 12 | Plots 1,4,12 | 1 | 46 | Plots 4,12 missing TKN; Plot 1 high TKN |
| Golay 2nd Derivative, avg 10 | Log TKN | 7.19.04 | 0.87 | 0.14 | 14 | Plot 5 | 1 | 9 | Plot 5 high reflectance |
| Untransformed | Excluding TKN >15 | 7.19.04 | 0.87 | 4.04 | 11 | Plots 1,5,6,13 | 3 | 74 | Plots 1,6,13 high TKN; Plot 5 high reflect. |
| Golay 1st Derivative | none | 6.29.04 | 0.81 | 4.38 | 12 | Plots 1,4,12 | 5 | 28 | Plots 4,12 missing TKN; Plot 1 high TKN |
| Untransformed (350-1075nm) | none | 7.19.04 | 0.79 | 4.78 | 14 | Plot 5 | 5 | 124 | Plot 5 high reflectance |
| Golay 2nd Derivative, avg 10 | none | 7.19.04 | 0.78 | 4.71 | 14 | Plot 5 | 1 | 64 | Plot 5 high reflectance |
| Kubelka-Munk Transform | none | 7.19.04 | 0.78 | 5.17 | 14 | Plot 5 | 4 | 159 | Plot 5 high reflectance |
| Golay 1st Derivative | none | 7.19.04 | 0.76 | 5.06 | 14 | Plot 5 | 6 | 212 | Plot 5 high reflectance |
| Transform 1/R | none | 7.19.04 | 0.68 | 5.78 | 15 | none | 4 | 130 | none |
| Absorbance Transformation | none | 7.19.04 | 0.66 | 5.66 | 14 | Plot 5 | 3 | 190 | Plot 5 high reflectance |
| Transform 1/R | Arcsine sqrt (TKN) | 7.19.04 | 0.65 | 0.09 | 14 | Plot 5 | 3 | 122 | Plot 5 high reflectance |
| Log R | none | 7.19.04 | 0.63 | 5.81 | 14 | Plot 5 | 3 | 181 | Plot 5 high reflectance |
| Log R | Sqrt TKN | 7.19.04 | 0.63 | 0.84 | 14 | Plot 5 | 3 | 189 | Plot 5 high reflectance |
| MSC Transformation | none | 7.19.04 | 0.63 | 5.89 | 14 | Plot 5 | 3 | 194 | Plot 5 high reflectance |

| Spectra Transformations | TKN Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | Number of sig. spectral bands | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.62 | 6.10 | 14 | Plot 5 | 3 | 99 | Plot 5 high reflectance |
| **Truncated spectra (400-950nm)** | **Log TKN** | 7.19.04 | 0.62 | 0.24 | 14 | Plot 5 | 3 | 184 | Plot 5 high reflectance |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt (TKN)** | 7.19.04 | 0.61 | 0.09 | 14 | Plot 5 | 5 | 158 | Plot 5 high reflectance |
| **Truncated spectra (400-950nm)** | **4th root TKN** | 7.19.04 | 0.61 | 0.25 | 14 | Plot 5 | 3 | 117 | Plot 5 high reflectance |
| **Truncated spectra (400-950nm)** | **Sqrt TKN** | 7.19.04 | 0.56 | 0.90 | 14 | Plot 5 | 3 | 156 | Plot 5 high reflectance |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.50 | 6.80 | 14 | Plot 5 | 3 | 172 | Plot 5 high reflectance |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.49 | 17.10 | 5 | none | 1 | none | none |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.48 | 32.60 | 5 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.32 | 7.32 | 11 | Plots 1,4,8,12 | 3 | 27 | Plots 4,12 missing TKN; Plot 1 high TKN; Plot 8 low reflect. |
| **PLS2 Untransformed** | **TKN, TP** | 7.19.04 | 0.18 | 8.07 | 14 | Plot 5 | 1 | none | Plot 5 high reflectance |
| **Golay 2nd Derivative, avg 10** | **Log TKN** | 8.24.04 | 0.16 | 0.16 | 14 | Plot 1 | 1 | none | Plot 1 high TKN conc |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.07 | 7.07 | 14 | Plot 1 | 1 | 145 | Plot 1 high TKN conc |
| **Norris 1st Derivative** | **Log TKN** | 8.24.04 | -0.01 | 0.31 | 15 | none | 1 | none | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | -0.04 | 28.32 | 14 | Plot 6 | 1 | 22 | Plot 6 high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | -0.06 | 29.79 | 15 | none | 1 | none | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | -0.08 | 29.72 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | -0.09 | 30.49 | 14 | Plot 6 | 1 | none | Plot 6 high reflectance |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | -0.10 | 30.51 | 14 | Plot 6 | 1 | none | Plot 6 high reflectance |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.14 | 25.92 | 15 | none | 1 | none | none |
| **Transform 1/R** | **none** | 8.24.04 | -0.17 | 26.64 | 15 | none | 1 | none | none |

**Table 3.4.14. PLS-regression transformations tested on TKN concentrations collected from the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt (TKN) | Truncated, 4th root TKN | Truncated Sqrt (TKN) | Truncated $Log_{10}$ TKN | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (TKN) | Log R | Log R, Sqrt (TKN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | |
| 7/19/2004 | X | X | X | X | X | X | | | | X | X | X | X |
| 8/24/2004 | X | X | | | | | X | X | X | X | | | |
| 9/21/2004 | X | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, Log TKN | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (TKN) | Excluding TKN > 15 | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | |
| 6/29/2004 | | X | X | X | X | | | | | |
| 7/19/2004 | X | X | X | X | X | X | X | X | X | X |
| 8/24/2004 | X | X | X | | X | | | | | |
| 9/21/2004 | | | | | | | | | | |

**Table 3.4.15. PLS-regression for total nitrogen at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | TKN Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.98 | 0.83 | 13 | Plots 12,14 | 4 | 6 | Plots 12,14 low TKN conc. |
| **Norris 1st Derivative** | **Log TKN** | 8.24.04 | 0.96 | 0.04 | 13 | Plots 12,14 | 7 | 21 | Plots 12,14 low TKN conc. |
| **Golay 2nd Derivative** | **none** | 7.19.04 | 0.91 | 1.45 | 14 | Plot 2 | 1 | 31 | Plot 2 high TKN conc. |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.90 | 1.62 | 13 | Plots 12,14 | 2 | 3 | Plots 12,14 low TKN conc. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.87 | 2.88 | 13 | Plots 10,13 | 5 | 20 | Plot 10 high reflect; Plot 13 high TKN |
| **Golay 2nd Derivative** | **Log TKN** | 8.24.04 | 0.79 | 0.08 | 13 | Plots 12,14 | 1 | 45 | Plots 12,14 low TKN conc. |
| **Truncated spectra, manual test set** | **none** | 8.24.04 | 0.62 | 3.28 | 5 | none | 1 | none | none |
| **Norris 1st Derivative, avg 5** | **none** | 8.24.04 | 0.60 | 3.12 | 13 | Plots 12,14 | 9 | 60 | Plots 12,14 low TKN conc. |
| **Golay 2nd Derivative** | **none** | 9.21.04 | 0.58 | 5.04 | 14 | Plot 12 | 1 | 9 | Plot 12 low reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.43 | 4.13 | 14 | Plot 14 | 2 | 36 | Plot 14 low TKN conc. |
| **Norris 1st Derivative** | **Log TKN** | 9.21.04 | 0.43 | 0.21 | 13 | Plots 10,13 | 1 | 5 | Plot 10 high reflect; Plot 13 high TKN |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.42 | 4.07 | 14 | Plot 14 | 1 | 9 | Plot 14 low TKN conc. |
| **Transform 1/R** | **none** | 8.24.04 | 0.42 | 3.54 | 13 | Plots 12,14 | 1 | 1 | Plots 12,14 low TKN conc. |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.42 | 3.62 | 13 | Plots 12,14 | 2 | 85 | Plots 12,14 low TKN conc. |
| **Golay 1st Derivative, avg 5** | **none** | 8.24.04 | 0.42 | 3.62 | 13 | Plots 12,14 | 2 | 85 | Plots 12,14 low TKN conc. |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.42 | 3.55 | 13 | Plots 12,14 | 1 | 1 | Plots 12,14 low TKN conc. |
| **Truncated spectra, random test set** | **none** | 8.24.04 | 0.41 | 3.37 | 5 | none | 1 | none | none |
| **Transform 1/R** | **Arcsine sqrt (TKN)** | 8.24.04 | 0.39 | 0.05 | 13 | Plots 12,14 | 1 | 2 | Plots 12,14 low TKN conc. |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.37 | 4.73 | 13 | Plots 1,6 | 1 | 123 | Plot 1 high reflect; Plot 6 low reflect |

| Spectra Transformations | TKN Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative, avg 10** | **none** | 8.24.04 | 0.37 | 3.61 | 13 | Plots 12,14 | 1 | 4 | Plots 12,14 low TKN conc. |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.35 | 2.62 | 14 | Plot 2 | 1 | 5 | Plot 2 high TKN conc. |
| **Log R** | **none** | 6.29.04 | 0.34 | 2.58 | 14 | Plot 12 | 2 | 107 | Plot 12 low TKN conc. |
| **Log R** | **Square root TKN** | 8.24.04 | 0.27 | 0.67 | 14 | Plot 14 | 1 | 41 | Plot 14 low TKN conc. |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.22 | 2.92 | 13 | Plots 2,5 | 3 | 13 | Plots 2,5 missing TKN |
| **Truncated spectra (400-950nm)** | **Arcsine sqrt (TKN)** | 8.24.04 | 0.20 | 0.07 | 14 | Plot 14 | 1 | 5 | Plot 14 low TKN conc. |
| **Truncated spectra (400-950nm)** | **Square root TKN** | 8.24.04 | 0.20 | 0.67 | 14 | Plot 14 | 1 | 5 | Plot 14 low TKN conc. |
| **Truncated spectra (400-950nm)** | **4th root TKN** | 8.24.04 | 0.17 | 0.19 | 14 | Plot 14 | 1 | 6 | Plot 14 low TKN conc. |
| **Golay 1st Derivative, avg 10** | **none** | 8.24.04 | 0.15 | 4.10 | 13 | Plots 12,14 | 1 | 115 | Plots 12,14 low TKN conc. |
| **Truncated spectra (400-950nm)** | **Log TKN** | 8.24.04 | 0.14 | 0.19 | 14 | Plot 14 | 1 | 5 | Plot 14 low TKN conc. |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.14 | 4.56 | 14 | Plot 14 | 1 | none | Plot 14 low TKN conc. |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.12 | 7.16 | 14 | Plot 6 | 1 | none | Plot 6 high reflectanc |
| **Golay 2nd Derivative** | **Log TKN** | 9.21.04 | 0.12 | 0.25 | 14 | Plot 12 | 1 | 2 | Plot 12 low reflectance |
| **MSC Transformation** | **none** | 8.24.04 | 0.03 | 5.26 | 13 | Plots 12,14 | 1 | none | Plots 12,14 low TKN conc. |
| **Log R** | **Square root TKN** | 6.29.04 | 0.02 | 0.56 | 15 | none | 1 | 127 | none |
| **Transform 1/R** | **none** | 9.21.04 | -0.26 | 6.14 | 14 | Plot 13 | 1 | none | Plot 13 high TKN conc. |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.53 | 7.28 | 15 | none | 1 | none | none |
| **Truncated spectra (400-950nm)** | **none** | 9.21.05 | -0.65 | 7.06 | 15 | none | 1 | none | none |

**Table 3.4.16. PLS-regressions transformations performed on TKN concentrations collected from the *Phragmites*-absent site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt (TKN) | Truncated, 4th root TKN | Truncated Sqrt (TKN) | Truncated $Log_{10}$ TKN | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (TKN) | Log R | Log R, Sqrt (TKN) | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | X | X | |
| 7/19/2004 | X | | | | | | | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| 9/21/2004 | X | X | | | | | | | | X | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, avg 5 | Norris 1st Derivative, avg 10 | Norris 1st Derivative, Log TKN | Golay 1st Derivative | Golay 1st Derivative, avg 5 | Golay 1st Derivative, avg 10 | Golay 2nd Derivative | Golay 2nd Deriv, Log (TKN) | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | Avg 5 wavelengths | Avg 10 wavelengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | | | | | | |
| 7/19/2004 | | | | | | | | X | | | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | X | X | | | X | X | | | | | | |

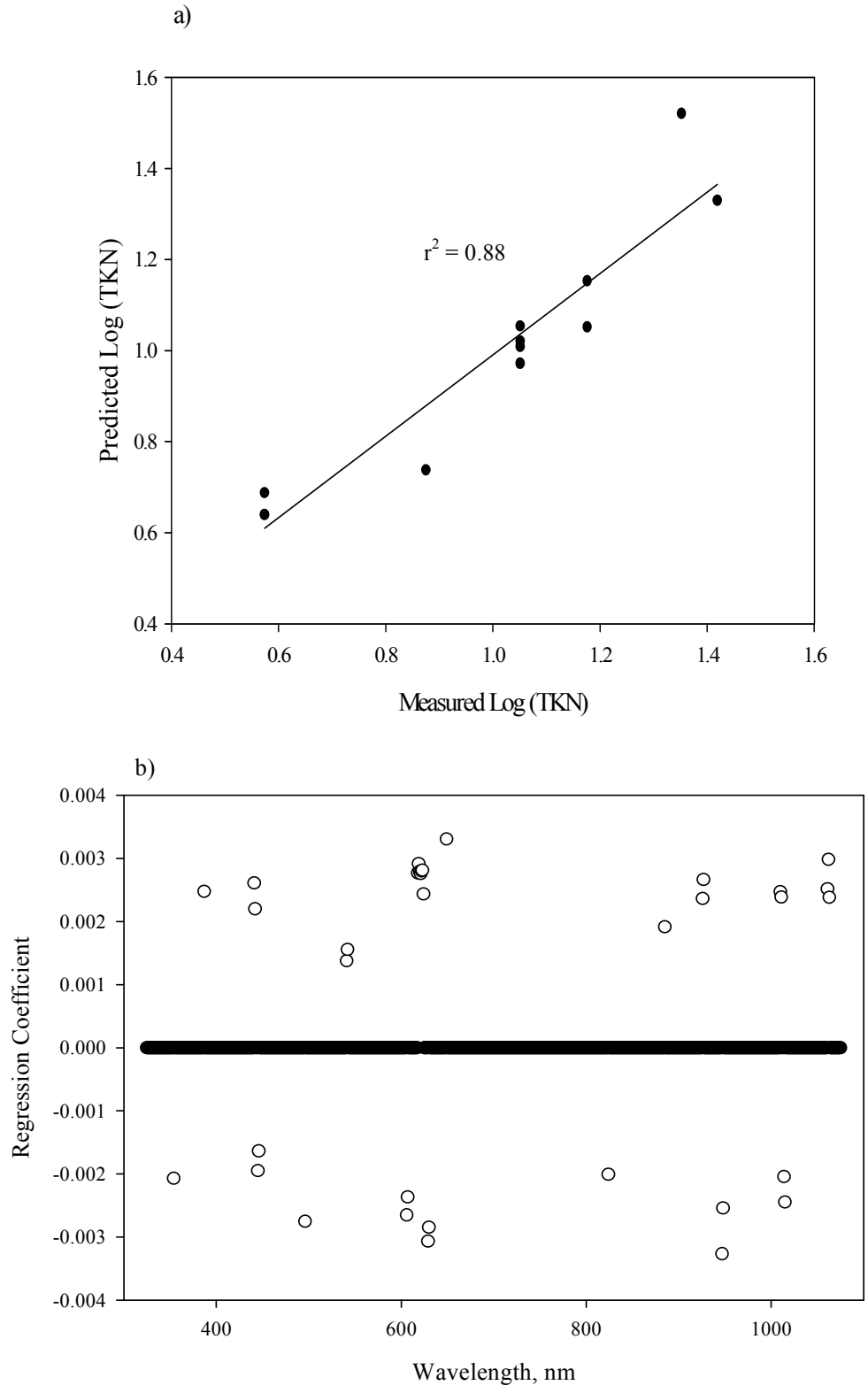



**Figure 3.4.16. (a) Predicted vs measured log of total nitrogen PLS-regression at the *Phragmites*-dominant site which used 33 spectral bands of the 1st derivative of the 6/29/04 reflectance to form three PLS-components with r = 0.94 and RMSEP of 0.09. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

At the *Phragmites*-absent site, the best PLS model used 115 spectral bands of 2nd derivative transformed reflectance that were combined into four PLS-components with RMSEP of 0.83 and $R^2 = 0.96$ (Figure 3.4.17).

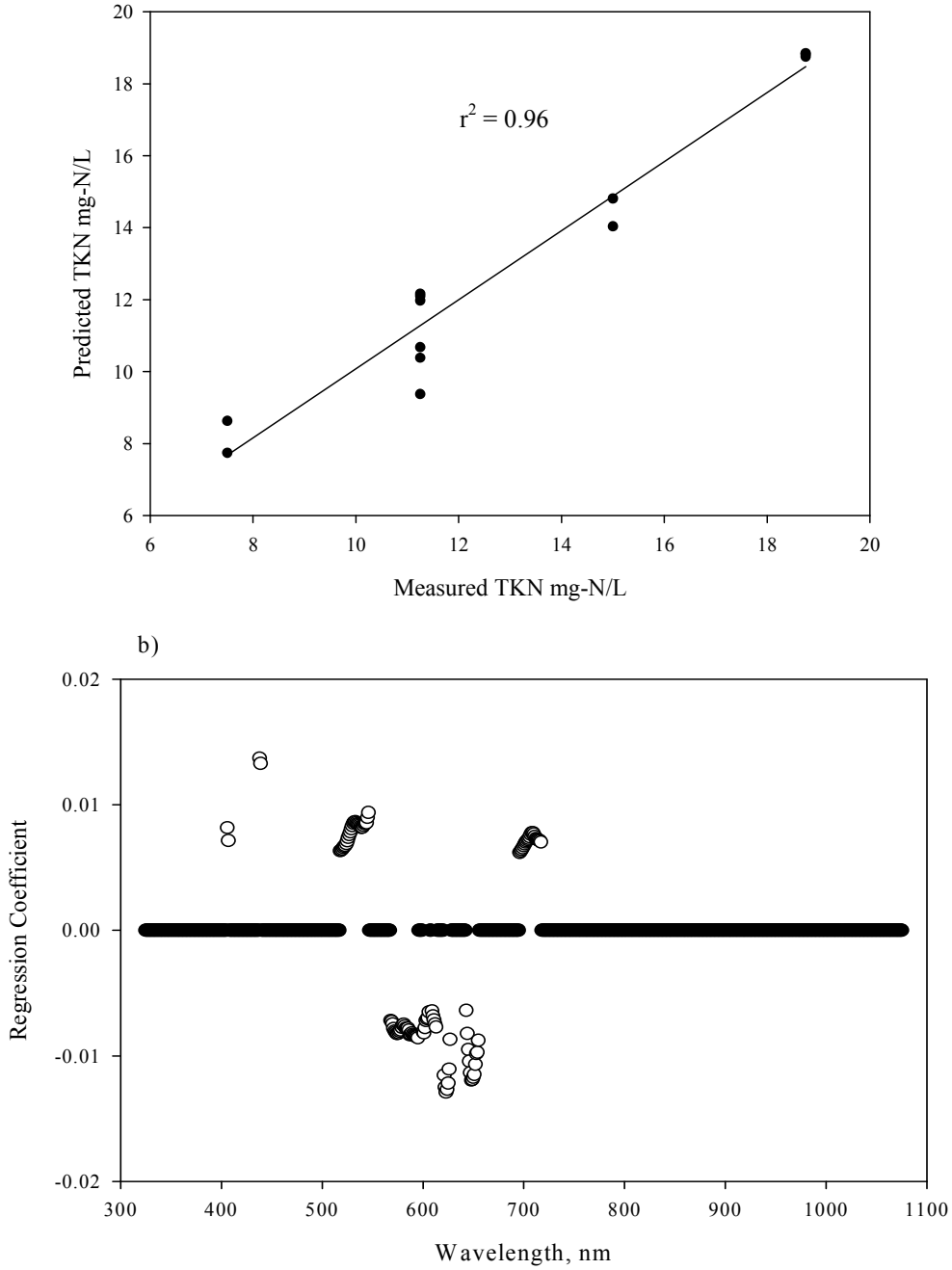



**Figure 3.4.17. (a) Predicted vs measured total nitrogen PLS-regression at the *Phragmites*-absent site which used 115 spectral bands of the 2nd derivative of the 8/24/04 reflectance to form four PLS-components with r = 0.98 and RMSEP of 0.83. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

Spectral bands used in the PLS models are summarized according to regression transformations for the *Phragmites*-dominant and *Phragmites*-absent sites (Figures 3.4.18 and 3.4.19, respectively). At the *Phragmites*-dominant site several models used similar spectral bands in the blue (420 – 510 nm), green (520 – 600 nm), and red-edge (700 – 710 nm), as Figure 3.4.18b further illustrates by highlighting spectral bands used in ten or more regressions. At the *Phragmites*-absent site, spectral bands in the green and red-edge were used in ten or more regressions (Figure 3.4.19). A list of the illustrated bands, significant to ten or more regressions, can be found in the Appendix.

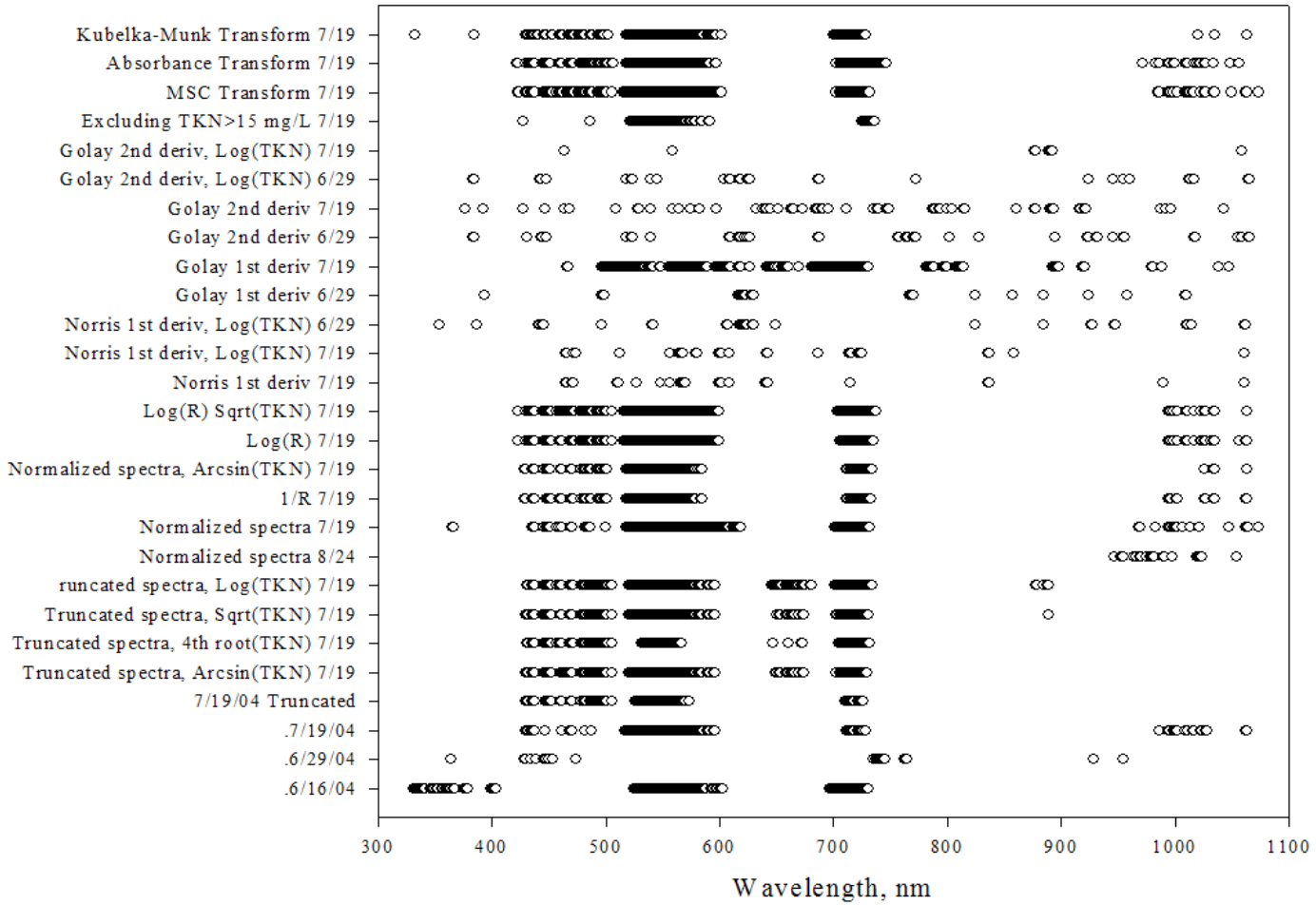



**Figure 3.4.18a. Significant spectral bands for total nitrogen according to PLS-regressions at the *Phragmites*-dominant site.**

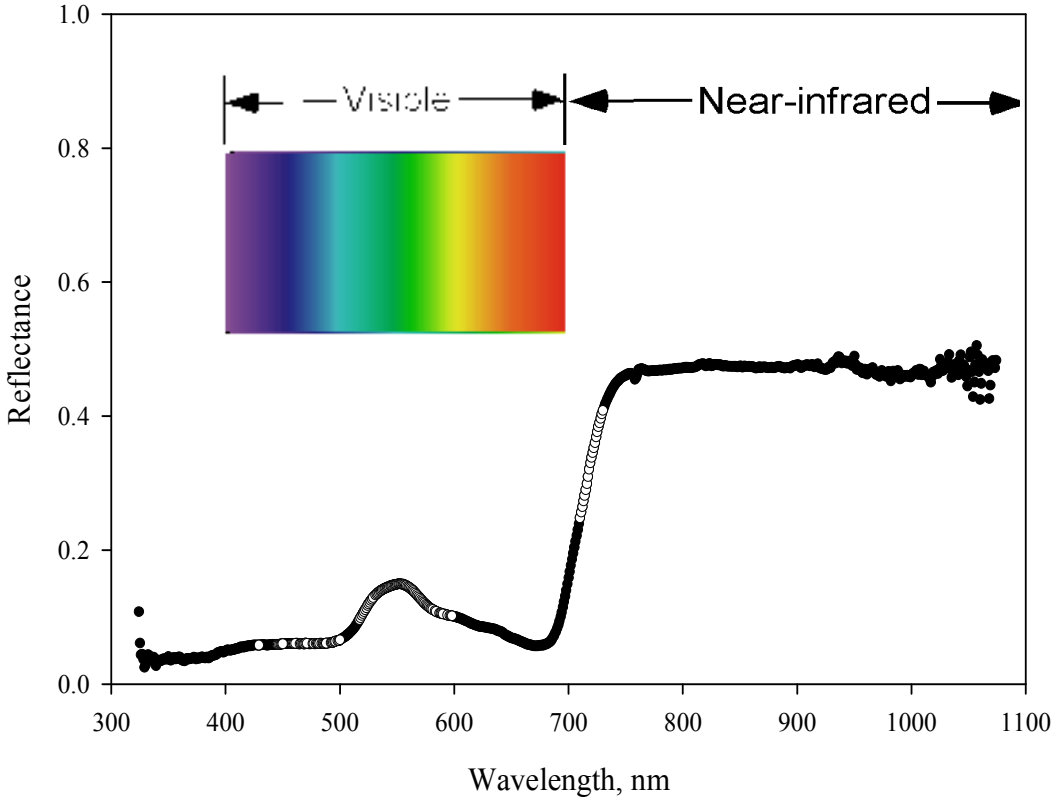



**Figure 3.4.18b. Spectral bands significant for ten or more regressions for total nitrogen at the *Phragmites*-dominant site are indicated by an open circle.**

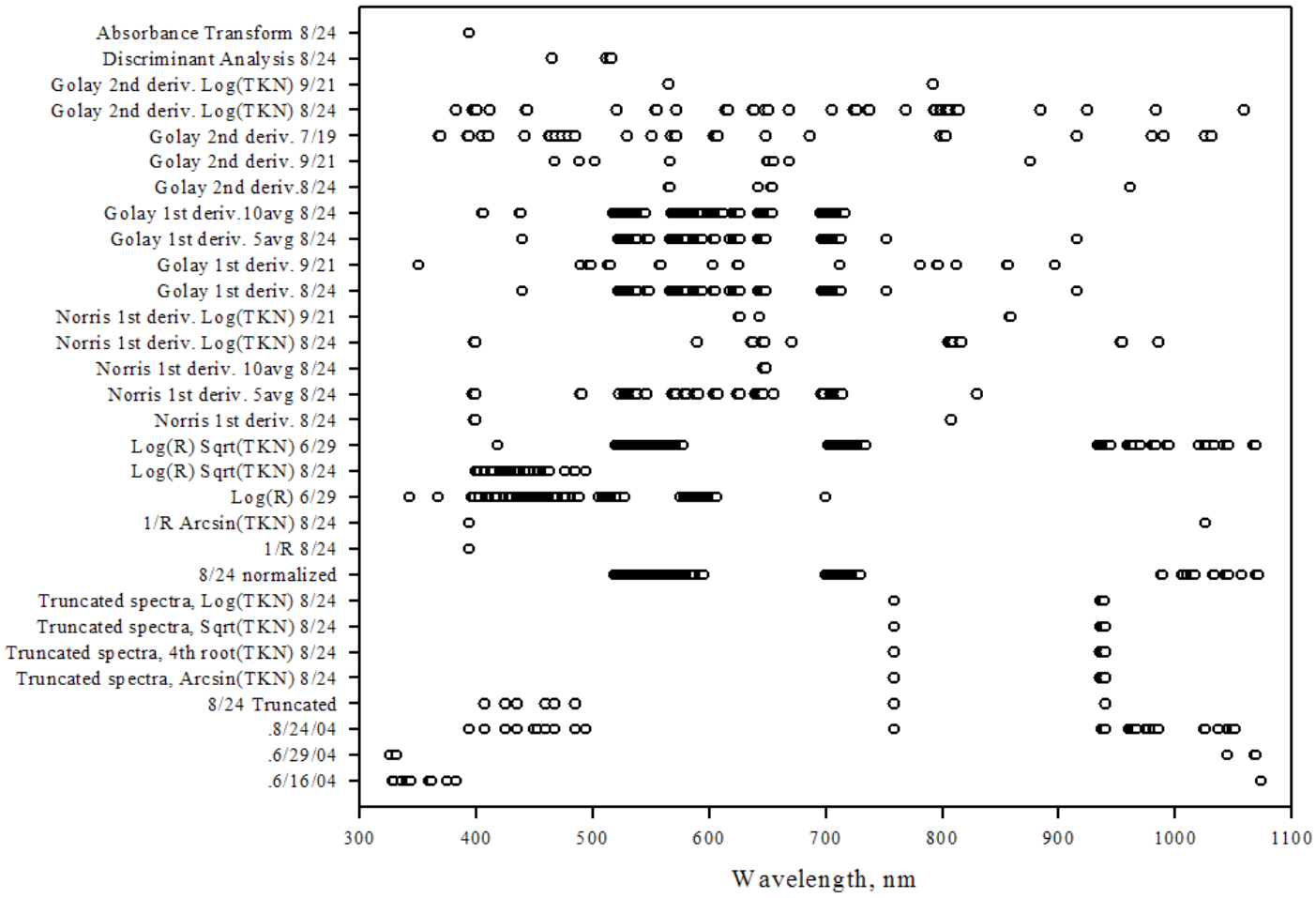



**Figure 3.4.19a. Significant spectral bands for total nitrogen according to PLS-regressions at the *Phragmites*-absent site.**

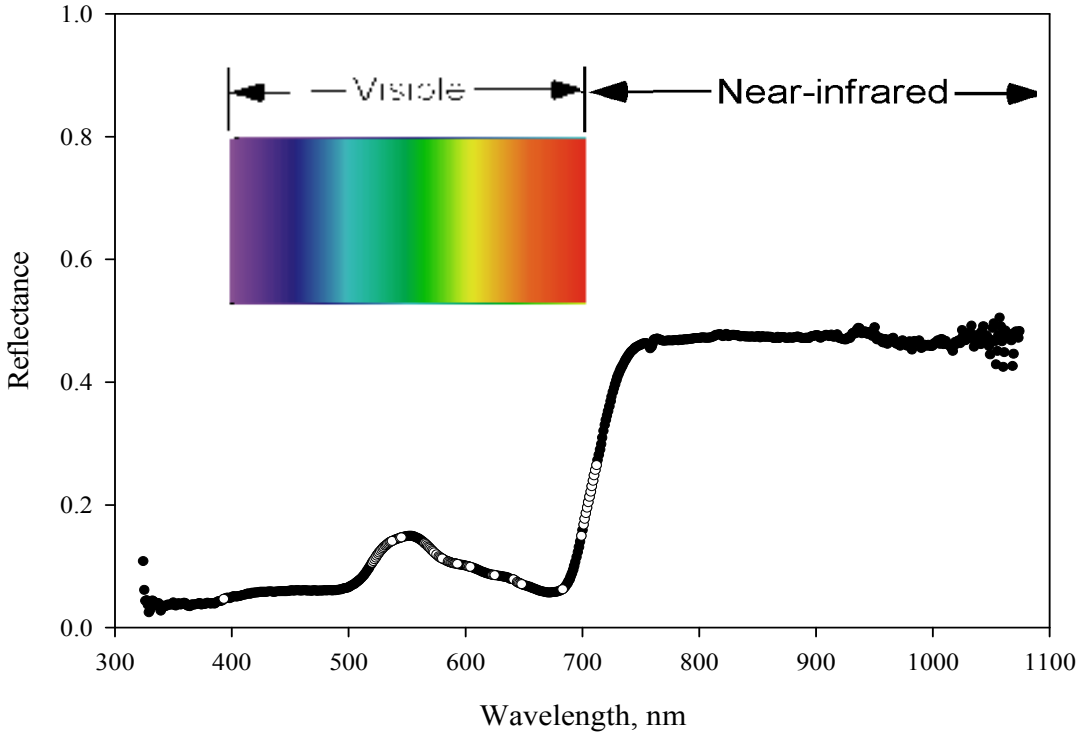



**Figure 3.4.19b. Spectral bands significant for ten or more regressions for total nitrogen at the *Phragmites*-absent site are indicated by an open circle.**

*PLS Models of Total Phosphorus*

PLS models at the *Phragmites*-dominant site were very successful at predicting total phosphorus concentrations, particularly during August and September of both years using the 1st and 2nd derivative of reflectance and log of total phosphorus (Table 3.4.17). The best PLS model at the *Phragmites*-dominant site used the log of total phosphorus (9/21/04 data) and seven spectral bands of first derivative transformed reflectance that were combined into one PLS-component with an RMSEP of 0.08 and $R^2 = 0.92$ (Figure 3.4.20). The second highest regression correlation used nine spectral bands of 1st derivative spectra combined into two PLS-components and untransformed total phosphorus (9/21/04 data), yielding an RMSEP of 0.02 and $R^2$ of 0.90 (Figure 3.4.21).

**Table 3.4.17. PLS-regression for total phosphorus at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | TP Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **Log TP** | 9.21.04 | 0.96 | 0.08 | 13 | Plots 2,3 | 1 | 7 | Plot 2 high reflect; Plot 3 low TP conc. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.95 | 0.02 | 14 | Plot 2 | 2 | 9 | Plot 2 high reflectance |
| **Norris 1st Derivative** | **none** | 9.21.04 | 0.90 | 0.03 | 14 | Plot 2 | 3 | 99 | Plot 2 high reflectance |
| **Golay 2nd Derivative** | **Log TP** | 8.24.04 | 0.83 | 0.27 | 13 | Plots 2,3 | 6 | 7 | Plots 2,3 low TP conc |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.82 | 0.16 | 14 | Plot 2 | 3 | 48 | Plot 2 low TP conc. |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.75 | 0.04 | 13 | Plots 2,7 | 2 | 67 | Plots 2,7 high reflect |
| **Golay 2nd Derivative** | **none** | 9.21.04 | 0.70 | 0.04 | 13 | Plots 2,3 | 1 | 13 | Plot 2 high reflect; Plot 3 low TP conc. |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.67 | 0.06 | 13 | Plots 2,9 | 3 | 91 | Plot 9 high reflect; Plot 2 low TP conc |
| **Golay 2nd Derivative** | **Log TP** | 7.19.04 | 0.65 | 0.36 | 12 | Plots 3,5,7 | 1 | 5 | Plots 3,5,7 low TP conc. |
| **Log R** | **Sqrt TP** | 9.21.04 | 0.60 | 0.10 | 14 | Plot 2 | 2 | 24 | Plot 2 high reflectance |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.59 | 0.08 | 14 | Plot 2 | 3 | 36 | Plot 2 low TP conc. |
| **Transform 1/R** | **none** | 9.21.04 | 0.56 | 0.05 | 14 | Plot 2 | 3 | 586 | Plot 2 high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.55 | 0.08 | 15 | none | 1 | 81 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.54 | 0.08 | 14 | Plot 2 | 1 | 82 | Plot 2 low TP conc. |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.52 | 0.06 | 13 | Plots 2,7 | 7 | 263 | Plots 2,7 high reflect |
| **Golay 2nd Derivative** | **none** | 8.24.04 | 0.50 | 0.07 | 14 | Plot 6 | 1 | 10 | Plot 6 high reflectance |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.49 | 0.08 | 15 | none | 1 | 17 | none |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.47 | 1.87 | 14 | Plot 15 | 3 | 91 | Plot 15 high reflect. |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (TP)** | 8.24.04 | 0.47 | 0.01 | 14 | Plot 2 | 1 | 414 | Plot 2 low TP conc. |

| Spectra Transformations | TP Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **Sqrt TP** | 8.24.04 | 0.47 | 0.13 | 14 | Plot 2 | 1 | 415 | Plot 2 low TP conc. |
| **Norris 1st Derivative** | **Log TP** | 8.24.04 | 0.44 | 0.40 | 13 | Plots 2,3 | 1 | 90 | Plots 2,3 low TP conc |
| **Golay 2nd Derivative** | **Log TP** | 9.21.04 | 0.43 | 0.28 | 14 | Plot 3 | 1 | 4 | Plot 3 low TP conc. |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.41 | 0.08 | 14 | Plot 2 | 1 | 330 | Plot 2 low TP conc. |
| **Transform 1/R** | **Arcsine sqrt (TP)** | 8.24.04 | 0.40 | 0.02 | 14 | Plot 2 | 3 | 20 | Plot 2 low TP conc. |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (TP)** | 7.19.04 | 0.38 | 0.02 | 14 | Plot 10 | 1 | 113 | Plot 10 low reflectance |
| **Untransformed (350-1075nm)** | **4th root TP** | 8.24.04 | 0.35 | 0.17 | 14 | Plot 2 | 1 | 420 | Plot 2 low TP conc. |
| **Log R** | **none** | 8.24.04 | 0.35 | 0.09 | 14 | Plot 2 | 1 | 334 | Plot 2 low TP conc. |
| **Untransformed (350-1075nm)** | **Log TP** | 8.24.04 | 0.31 | 0.42 | 13 | Plots 2,3 | 1 | 416 | Plots 2,3 low TP conc |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.31 | 0.06 | 5 | none | 1 | none | Remaining samples used in calibration |
| **Log R** | **Sqrt TP** | 8.24.04 | 0.31 | 0.15 | 14 | Plot 2 | 2 | 399 | Plot 2 low TP conc. |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.28 | 0.18 | 14 | Plot 10 | 1 | 79 | Plot 10 low reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.27 | 0.09 | 14 | Plot 2 | 1 | 12 | Plot 2 low TP conc. |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.26 | 0.18 | 14 | Plot 10 | 1 | 63 | Plot 10 low reflectance |
| **MSC Transformation** | **none** | 8.24.04 | 0.17 | 0.12 | 15 | none | 1 | none | none |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.14 | 0.11 | 4 | Plot 2 | 1 | none | Remaining samples used in calibration |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | -0.11 | 0.56 | 13 | Plots 4,12 | 1 | none | Plots 4,12 missing |

**Table 3.4.18. PLS-regressions transformations tested on total phosphorus concentrations collected at the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt (TP) | Truncated, 4th root TP | Truncated Sqrt (TP) | Truncated $Log_{10}$ TP | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (TP) | Log R | Log R, Sqrt (TP) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | |
| 7/19/2004 | X | X | X | | | | | | | | | | |
| 8/24/2004 | X | | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | X | | | | | | | | X | | | X |
| 6/6/2005 | X | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, Log TP | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (TP) | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | |
| 7/19/2004 | | | | | X | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | X | X | X | X | | | | | |
| 6/6/2005 | | | | | | | | | | |

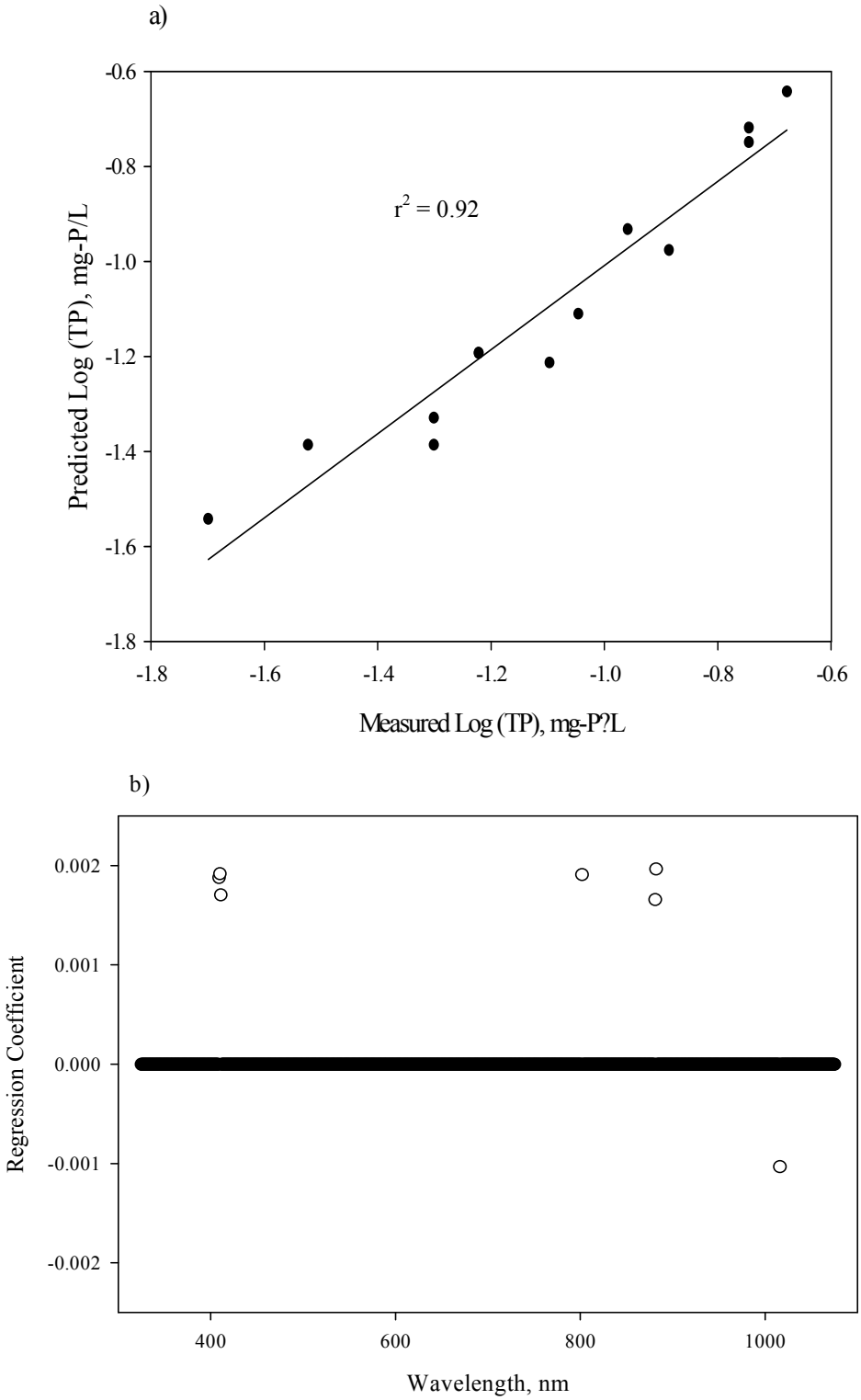



**Figure 3.4.20. (a) Predicted vs measured log of total phosphorus PLS-regression at the *Phragmites*-dominant site which used seven spectral bands of the 1st derivative of the 9/21/04 reflectance to form one PLS-component with r = 0.96 and RMSEP of 0.08. (b) Loading plot showing significant spectral bands used in the regression as open circles.**

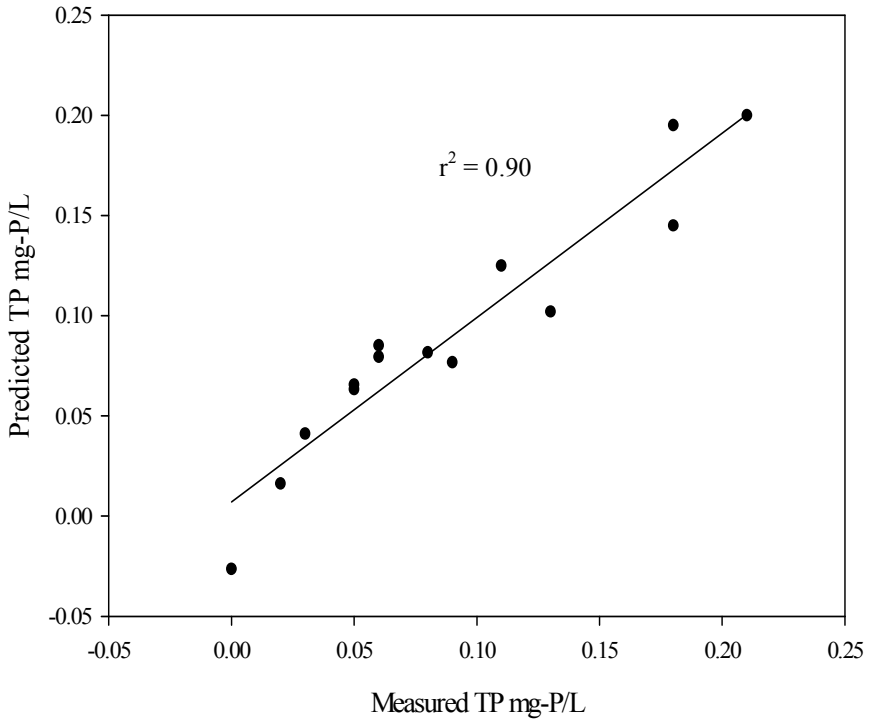



**Figure 3.4.21. Predicted vs measured total phosphorus PLS-regression at the *Phragmites*-dominant site which used nine spectral bands of the 1st derivative of the 9/21/04 reflectance to form two PLS-components with r = 0.95 and RMSEP of 0.02.**

At the *Phragmites*-absent site, PLS models were capable of quantifying total phosphorus concentrations for untransformed spectra during July and August (Table 3.4.19). The best PLS model used 73 spectral bands from the 7/19/04 sample date that formed three PLS-components with RMSEP of 0.06 and $R^2 = 0.79$ (Figure 3.2.22).

**Table 3.4.19. PLS-regression for total phosphorus at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | TP Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.89 | 0.06 | 14 | Plot 2 | 3 | 73 | Plot 2 high TP conc. |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.86 | 0.07 | 14 | Plot 2 | 4 | 89 | Plot 2 high TP conc. |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.85 | 0.05 | 13 | Plots 7,12 | 3 | 10 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Transform 1/R** | **none** | 9.21.04 | 0.84 | 0.05 | 13 | Plots 7,12 | 8 | 28 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.83 | 0.04 | 14 | Plot 7 | 3 | 88 | Plot 7 high TP conc |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.77 | 0.06 | 15 | none | 4 | 73 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.75 | 0.05 | 14 | Plot 7 | 3 | 76 | Plot 7 high TP conc |
| **Log R** | **Sqrt TP** | 8.24.04 | 0.74 | 0.07 | 14 | Plot 7 | 3 | 26 | Plot 7 high TP conc |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (TP)** | 7.19.04 | 0.72 | 0.00 | 14 | Plot 2 | 3 | 192 | Plot 2 high TP conc. |
| **Norris 1st Derivative** | **Log TP** | 9.21.04 | 0.71 | 0.24 | 15 | none | 1 | 32 | none |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.68 | 0.06 | 13 | Plots 7,12 | 3 | 53 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Log R** | **Sqrt TP** | 9.21.04 | 0.68 | 0.09 | 13 | Plots 7,12 | 2 | 32 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Transform 1/R** | **Arcsine sqrt (TP)** | 8.24.04 | 0.66 | 0.01 | 15 | none | 3 | 53 | none |
| **Golay 2nd Derivative** | **Log TP** | 9.21.04 | 0.65 | 0.26 | 15 | none | 1 | 32 | none |
| **MSC Transformation** | **none** | 8.24.04 | 0.64 | 0.07 | 15 | none | 1 | 228 | none |
| **Truncated spectra, random test** | **none** | 8.24.04 | 0.61 | 0.05 | 5 | none | 1 | none | Remaining samples used for calibration |
| **Norris 1st Derivative** | **none** | 9.21.04 | 0.60 | 0.07 | 13 | Plots 7,12 | 1 | 15 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.58 | 0.07 | 13 | Plots 7,12 | 2 | 3 | Plot 7 high TP conc; Plot 12 high reflect. |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.55 | 0.06 | 14 | Plot 7 | 1 | 222 | Plot 7 high TP conc |

| Spectra Transformations | TP Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Golay 2nd Derivative** | **none** | 9.21.04 | 0.55 | 0.10 | 15 | none | 1 | 15 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.53 | 0.06 | 14 | Plot 7 | 1 | 194 | Plot 7 high TP conc |
| **Log R** | **none** | 8.24.04 | 0.51 | 0.06 | 14 | Plot 7 | 1 | 511 | Plot 7 high TP conc |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.50 | 0.08 | 15 | none | 2 | 4 | none |
| **Transform 1/R** | **none** | 8.24.04 | 0.50 | 0.08 | 15 | none | 3 | 458 | none |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (TP)** | 8.24.04 | 0.49 | 0.00 | 15 | none | 2 | 61 | none |
| **Untransformed (350-1075nm)** | **Sqrt TP** | 8.24.04 | 0.49 | 0.10 | 15 | none | 2 | 60 | none |
| **Untransformed (350-1075nm)** | **Log TP** | 8.24.04 | 0.49 | 0.25 | 15 | none | 4 | 25 | none |
| **Golay 2nd Derivative** | **none** | 8.24.04 | 0.49 | 0.08 | 15 | none | 1 | 53 | none |
| **Golay 2nd Derivative** | **Log TP** | 8.24.04 | 0.49 | 0.24 | 15 | none | 1 | 61 | none |
| **Untransformed (350-1075nm)** | **4th root TP** | 8.24.04 | 0.48 | 0.08 | 15 | none | 2 | 50 | none |
| **Golay 2nd Derivative** | **Log TP** | 7.19.04 | 0.47 | 0.28 | 15 | none | 1 | 12 | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.41 | 0.09 | 14 | Plot 2 | 6 | 57 | Plot 2 missing TP |
| **Norris 1st Derivative** | **Log TP** | 8.24.04 | 0.40 | 0.23 | 14 | Plot 7 | 1 | 179 | Plot 7 high TP conc |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.12 | 0.35 | 13 | Plots 3,10 | 1 | none | Plot 3 high reflect; Plot 10 high TP conc |
| **Truncated spectra, manual test** | **none** | 8.24.04 | 0.11 | 0.11 | 5 | none | 4 | none | Remaining samples used for calibration |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.03 | 0.91 | 13 | Plots 5,9 | 1 | none | Plot 5 missing TP, Plot 9 high TP conc. |

**Table 3.4.20. PLS-regressions transformations tested on total phosphorus concentrations collected at the *Phragmites*-absent site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Truncated, Arcsine sqrt (TP) | Truncated, 4th root TP | Truncated Sqrt (TP) | Truncated $Log_{10}$ TP | Truncated Manual test set | Truncated Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (TP) | Log R | Log R, Sqrt (TP) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | X | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | |
| 7/19/2004 | X | X | X | | | | | | | | | | |
| 8/24/2004 | X | | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | X | | | | | | | | X | | | X |
| 6/6/2005 | X | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Derivative, Log TP | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (TP) | Discriminant Analysis | MSC Transform | Absorbance Transform | Kubelka-Munk Transform | PLS2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/16/2004 | | | | | | | | | | |
| 6/29/2004 | | | | | | | | | | |
| 7/19/2004 | | | | | X | | | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | X | X | X | X | | | | | |
| 6/6/2005 | | | | | | | | | | |

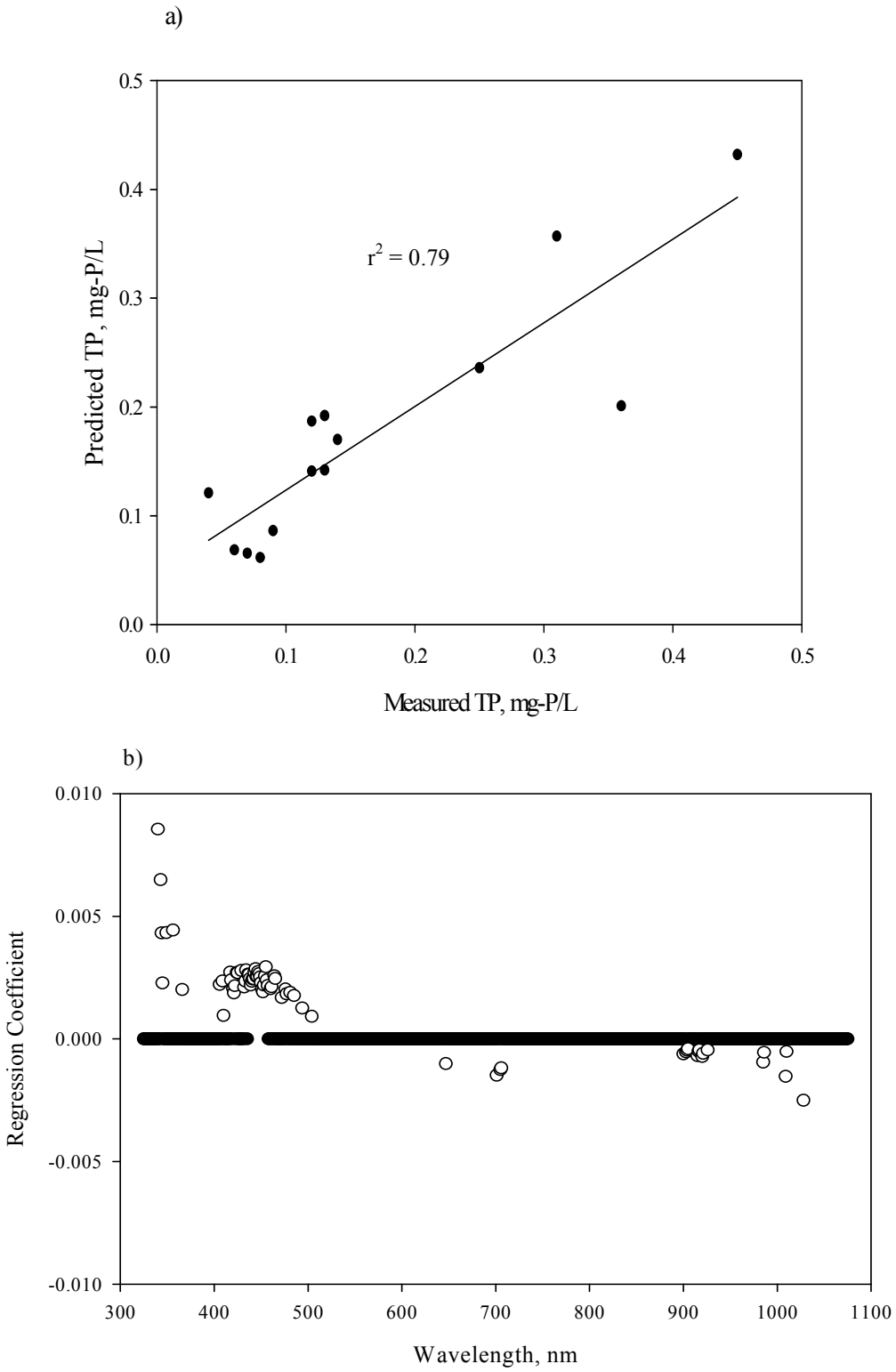



**Figure 3.4.22. (a) Predicted vs measured total phosphorus PLS-regression at the *Phragmites*-absent site which used 73 untransformed spectral bands from 7/19/04 to form three PLS-components with r = 0.89 and RMSEP of 0.06. (b) Loading plot shows significant spectral bands used in the regression as open circles.**

A summary of spectral bands used in each PLS model predicting phosphorus concentrations at the *Phragmites*-dominant site shows that regressions using a transformation of total phosphorus (log, square root, fourth root) used more spectral bands than untransformed total phosphorus data (Figure 3.4.23a). Spectral bands used in ten or more regressions were in the green and near-infrared wavebands (Figure 3.4.23b). Spectral bands used at the *Phragmites*-absent site are primarily concentrated in the visible green, with a few in the near-infrared (Figure 3.4.24b). A list of the illustrated bands, significant to ten or more regressions, can be found in the Appendix.

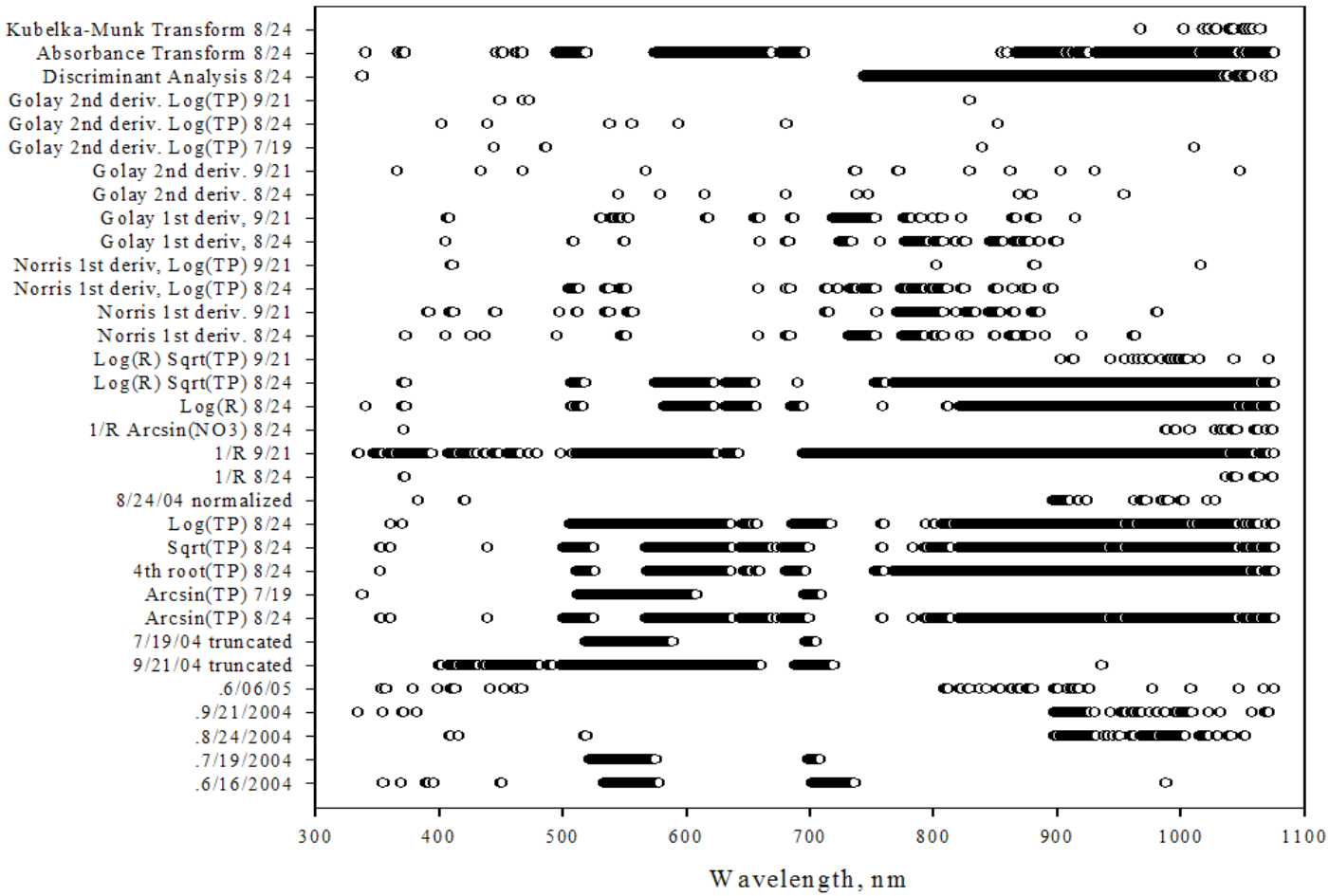



**Figure 3.4.23a. Significant spectral bands for total phosphorus according to PLS-regressions at the *Phragmites*-dominant site.**

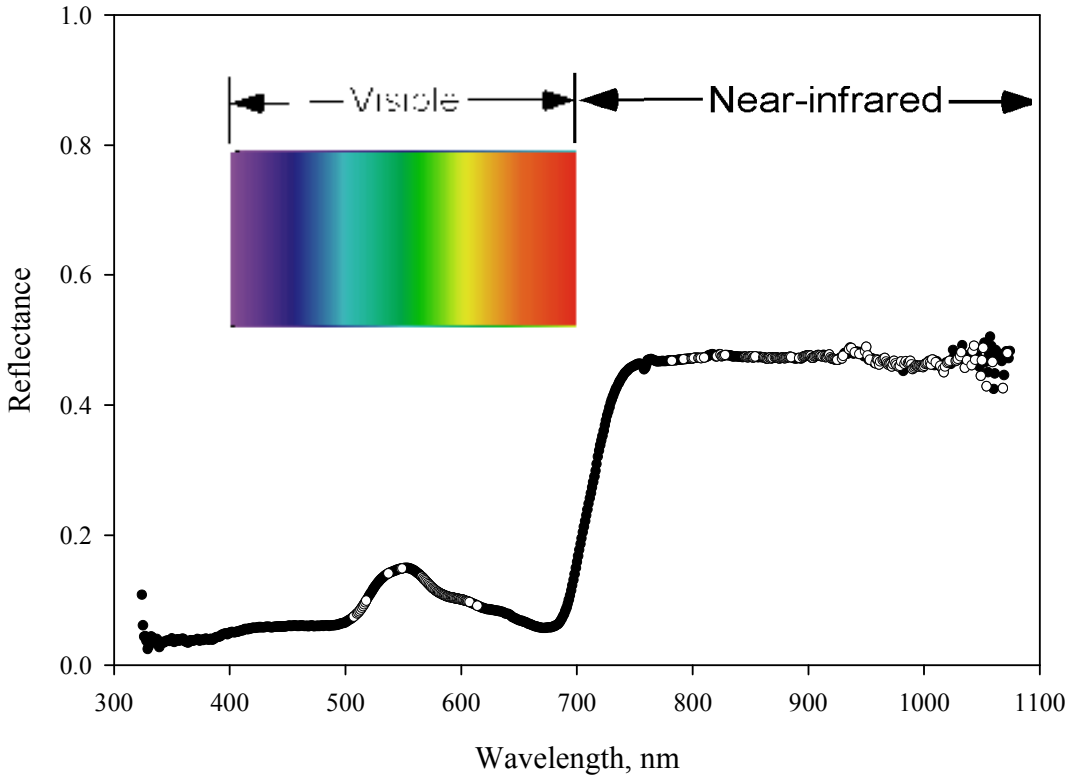



**Figure 3.4.23b. Spectral bands significant for ten or more regressions for total phosphorus at the *Phragmites*-dominant site are indicated by an open circle.**

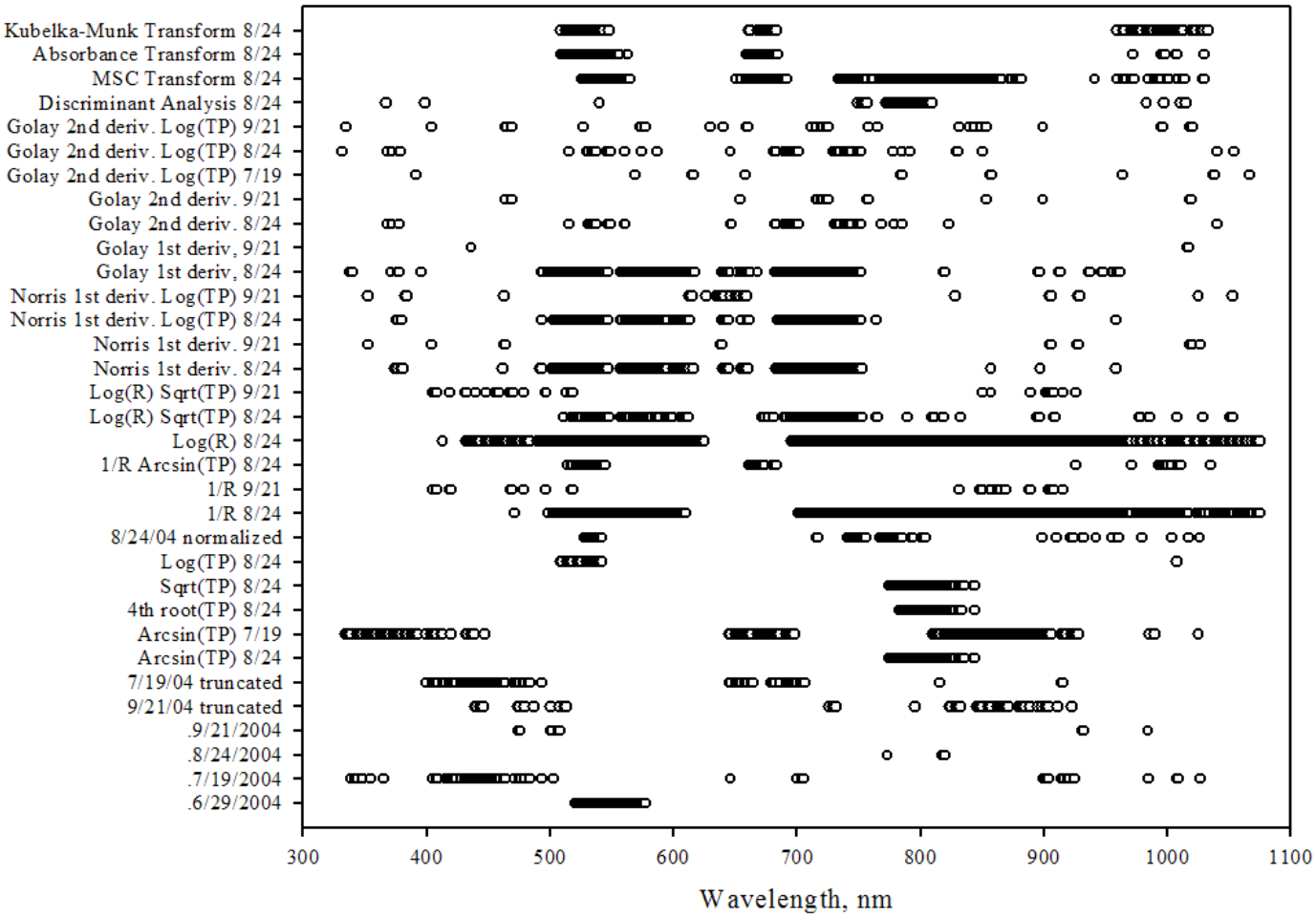



**Figure 3.4.24a. Significant spectral bands for total phosphorus according to PLS-regressions at the *Phragmites*-absent site.**

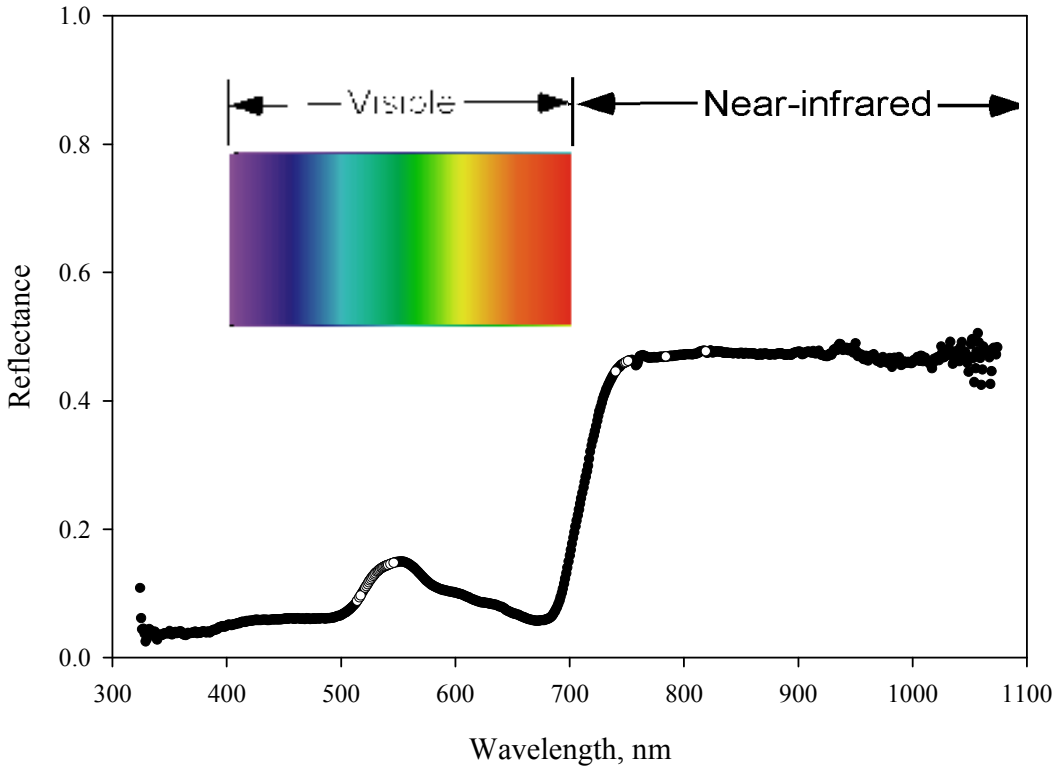



**Figure 3.4.24b. Spectral bands significant for ten or more regressions for total phosphorus at the *Phragmites*-absent site are indicated by an open circle.**

*3.4.2 Prediction of canopy nutrients*

Since it would be useful to detect vegetation nutrient concentrations using remote sensing techniques, we explored the ability of PLS-regression to quantify canopy nitrogen, canopy phosphorus and biomass within our study sites.

PLS was able to quantify canopy nitrogen, canopy phosphorus and biomass for all thirty marsh plots (Table 3.4.21). Canopy nitrogen ($g/m^2$ and %) and biomass were best predicted with the first derivative of the reflectance ($R^2$ = 0.77, 0.80, and 0.83, respectively), while canopy phosphorus was best predicted using the second derivative of the reflectance ($R^2$ = 0.76 and $R^2$ = 0.71) (Table 3.4.21).

**Table 3.4.21. PLS-regressions for leaf nitrogen, leaf phosphorus, and plot biomass for all thirty plots on 8/02/05. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands**

| Species | Cover range | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|
| Canopy N | 4 - 43 ($g/m^2$) | 0.67 | 4.6 | 2 | untransformed | 19 |
| | 5 - 43 ($g/m^2$) | 0.77 | 4.4 | 2 | 1st derivative | 11 |
| | 6 - 43 ($g/m^2$) | 0.67 | 5.4 | 3 | 2nd derivative | 8 |
| | 1 - 2.3 (%) | 0.64 | 0.2 | 4 | untransformed | 45 |
| | 1.2 - 2.7 (%) | 0.80 | 0.1 | 3 | 1st derivative | 35 |
| | 1.3 - 2.7 (%) | 0.70 | 0.2 | 1 | 2nd derivative | 14 |
| Canopy P | 0.7 - 2.7 ($g/m^2$) | 0.30 | 0.6 | 1 | untransformed | 446 |
| | 0.7 - 2.8 ($g/m^2$) | 0.44 | 0.5 | 1 | 1st derivative | 298 |
| | 0.7 - 2.9 ($g/m^2$) | 0.76 | 0.3 | 2 | 2nd derivative | 19 |
| | 0.2 - 0.4 (%) | 0.00 | 0.1 | 1 | untransformed | - |
| | 0.2 - 0.4 (%) | 0.04 | 0.0 | 1 | 1st derivative | 27 |
| | 0.2 - 0.4 (%) | 0.71 | 0.0 | 3 | 2nd derivative | 10 |
| Biomass | 190 - 2300 g | 0.79 | 294.0 | 3 | untransformed | 122 |
| | 191 - 2300 g | 0.83 | 258.4 | 2 | 1st derivative | 17 |
| | 192 - 2300 g | 0.61 | 390.1 | 1 | 2nd derivative | 15 |

Total canopy nitrogen of the plot was compared to canopy nitrogen relative to the total biomass of the plot (Table 3.4.22). The PLS regressions yielded similar $R^2$'s and the two models both used spectral bands 735 – 739 nm (Figure 3.4.25).

**Table 3.4.22. PLS-regressions for canopy nitrogen of the plot ($g/m^2$) and in reference to total biomass (%) for all thirty plots on 8/02/05. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands used in the PLS-regression.**

| Response | Data Range | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|
| Leaf N ($g/m^2$) | 4 - 43 | 0.67 | 4.6 | 2 | 350 - 1075 nm | 19 |
| Leaf N (%) | 1 - 2.3 | 0.64 | 0.2 | 4 | 350 - 1075 nm | 45 |

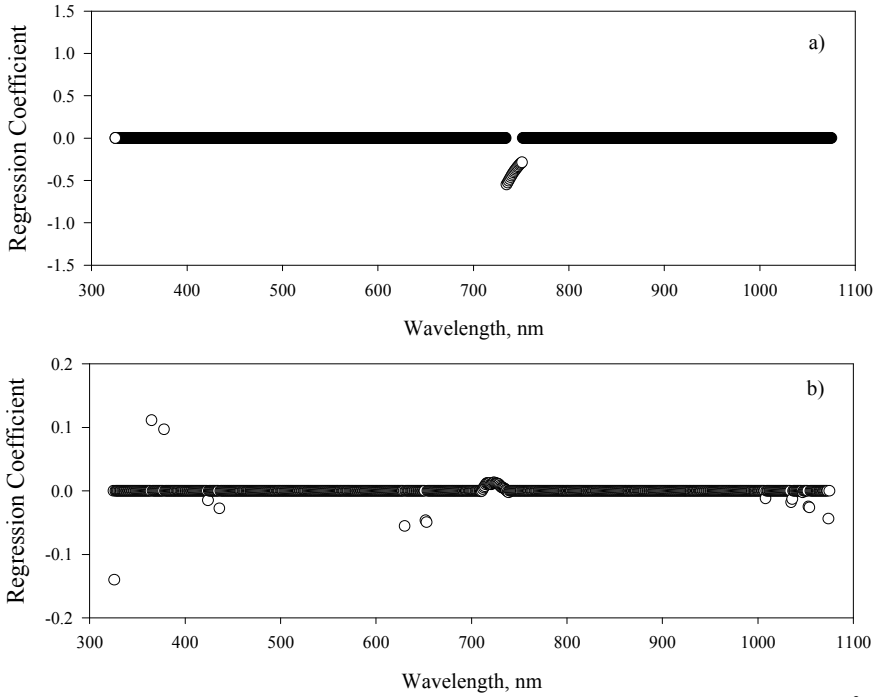



**Figure 3.4.25. PLS regression coefficients for (a) canopy nitrogen of the plot ($g/m^2$) and (b) canopy nitrogen according to total biomass (%) using untransformed reflectance data.**

No spectral band used in any PLS-regression for canopy nitrogen (transformations 350 – 1075 nm, 1st derivative R, 2nd derivative R) was shared between regressions (Figure 3.4.26a, b, and c). Phosphorus PLS-regressions, however, used several similar spectral bands, including single bands in the visible and near-infrared and a

cluster of spectral bands at the red-edge, in all three regressions (Figure 3.4.26d, e, and f). Biomass PLS-regressions shared spectral bands at 600 nm for all three regressions (Figure 3.4.26g, h, and i).

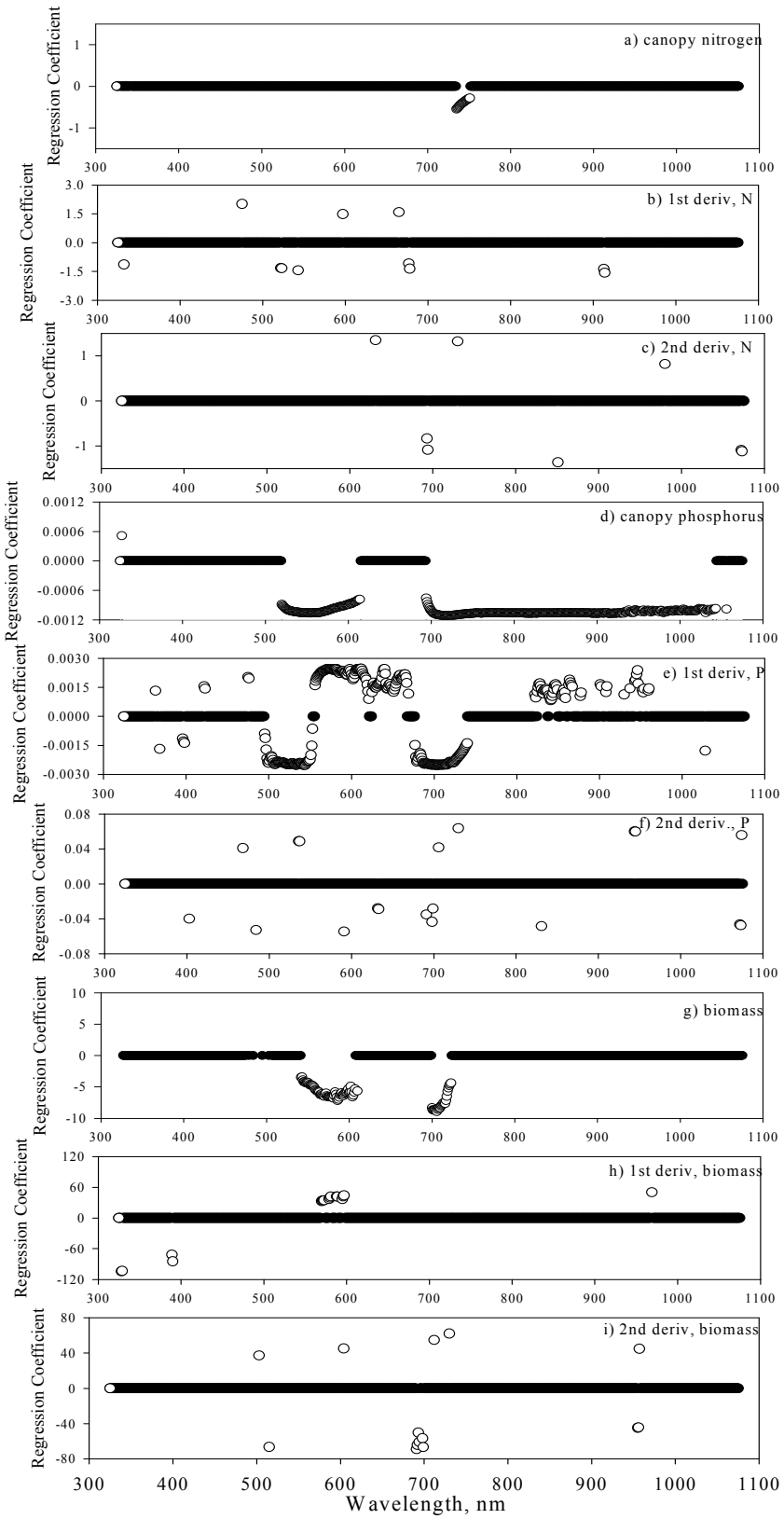



**Figure 3.4.26. PLS regression coefficients for (a) canopy nitrogen, (b) 1st derivative R, canopy N, (c) 2nd derivative R, canopy N, (d) canopy phosphorus, (e) 1st derivative R, canopy P, (f) 2nd derivative R, canopy P, (g) biomass, (h) 1st derivative R, biomass, (i) 2nd derivative R, biomass.**

*3.4.3 Prediction of vegetation composition and surface cover*

We explored the ability of PLS-regression to quantify the percent cover of six common plant species that were present at our study sites because assessment of marsh vegetation composition with remote sensing could improve the frequency and reduce the cost of wetland assessment.

PLS was able to adequately quantify (i.e., $R^2 > 0.70$) species cover of five of the six species as well as cover of dead material and exposed soil (Table 3.4.23). The amount of exposed soil at the *Phragmites*-dominant site had the overall best PLS model, using 351 untransformed spectral bands from the August 2004 sample date to form six PLS-components with an $R^2$ of 0.94 and RMSEP of 3.6%. *P. australis*, *A. calamus*, *P. virginica* and dead material cover also had high coefficients of determination, which indicates that hyperspectral reflectance may be capable of identifying the mix of dominant species, the cover of dead vegetation and cover of soil in marshes. *Typha* species at the *Phragmites*-absent site and dead material at the *Phragmites*-dominant site had weaker predictive PLS models ($R^2$=0.67 each and RMSEP= 0.4% and 15.3%, respectively; Table 3.4.23). Other PLS models tested, but found to be less predictive than those in Table 3.4.23 can be found in the Appendix.

Unfortunately, the PLS models best at predicting species at one marsh site did not transfer well to the other site (Table 3.4.24). For example, the best PLS model of exposed soil at the *Phragmites*-dominant site with an $R^2$ of 0.94 (untransformed August 2004 data) yielded an $R^2$ of 0.01 at the *Phragmites*-absent site.

**Table 3.4.23. The best PLS-regression(s) for each species cover at individual marsh sites. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands used in the PLS-regression.**

| Species | Site | Cover range | Date | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|---|---|
| *P. australis* | PD | 5 - 90 | 8.02.05 | 0.85 | 12.0 | 3 | 1st derivative | 142 |
| *A. calamus* | PD | 0 - 65 | 6.16.04 | 0.85 | 6.8 | 8 | 1/R | 128 |
| | PD | 0 - 65 | 6.16.04 | 0.85 | 6.8 | 8 | 1/R,arcsin (cover)$^{1/2}$ | 128 |
| *P. arifolium* | PD | 0 - 60 | 9.21.04 | 0.74 | 8.9 | 3 | 350 - 1075nm | 27 |
| | PA | 30 - 100 | 8.24.04 | 0.79 | 7.7 | 3 | R/R410 | 169 |
| *P. virginica* | PD | 0 - 40 | 5.25.04 | 0.83 | 7.6 | 3 | 400 - 950nm | 27 |
| | PA | 0 - 18 | 9.21.04 | 0.86 | 0.5 | 4 | Log R,(cover)$^{1/2}$ | 243 |
| *Typha sp.* | PA | 0 - 1.5 | 8.24.04 | 0.67 | 0.4 | 4 | Log R | 13 |
| *I. capensis* | PD | 0 - 70 | 7.19.04 | 0.81 | 10.7 | 4 | 1st deriv (Norris) | 45 |
| | PD | 0 - 70 | 7.19.04 | 0.81 | 10.9 | 2 | 1st deriv.(Golay) | 60 |
| | PD | 0 - 65 | 8.24.04 | 0.81 | 0.9 | 9 | Log R,(cover)$^{1/2}$ | 44 |
| | PA | 0 - 90 | 7.19.04 | 0.81 | 13.0 | 3 | 1/R | 26 |
| | PA | 0 - 90 | 7.19.04 | 0.79 | 15.0 | 8 | Log R | 59 |
| Dead | PD | 0 - 90 | 9.21.04 | 0.67 | 15.3 | 6 | 350-1075nm | 34 |
| | PA | 0 - 20 | 5.25.04 | 0.85 | 2.0 | 3 | 350-1075nm | 165 |
| Exposed | PD | 0 - 40 | 8.24.04 | 0.94 | 3.6 | 6 | 350-1075nm | 351 |
| | PA | 0 - 18 | 7.19.04 | 0.83 | 0.5 | 2 | 2nd deriv. | 88 |

**Table 3.4.24. The best PLS models of each species cover applied to the opposite marsh site. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands used in the PLS-regression. Regressions were not performed for *P. australis* and *A. calamus* at the PD site and *Typha* species at the PA site because the species was not present at that site.**

| Species | Site | Cover range | Date | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|---|---|
| *P. australis* | N/A | - | - | - | - | - | - | - |
| *A. calamus* | N/A | - | - | - | - | - | - | - |
| | N/A | - | - | - | - | - | - | - |
| *P. arifolium* | PA | 0 - 18 | 9.21.04 | 0.28 | 5.0 | 3 | 350 - 1075 nm | 60 |
| | PD | 3 - 100 | 8.24.04 | 0.59 | 17.4 | 3 | R/R410 | 4 |
| *P. virginica* | PA | 0 - 8 | 8.24.04 | 0.64 | 1.2 | 3 | 400 - 950 nm | 56 |
| | PD | 0 - 65 | 6.03.04 | 0.30 | 0.7 | 9 | Log R, $(cover)^{1/2}$ | 353 |
| *Typha sp.* | N/A | - | - | - | - | - | - | - |
| *I. capensis* | PA | 0 - 90 | 7.19.04 | 0.55 | 20.2 | 1 | $1^{st}$ deriv (Norris) | 20 |
| | PA | 0 - 90 | 7.19.04 | 0.58 | 19.8 | 3 | $1^{st}$ deriv (Golay) | 10 |
| | PA | 0 - 85 | 8.24.04 | 0.71 | 1.7 | 5 | Log R, $(cover)^{1/2}$ | 42 |
| | PD | 0 - 70 | 7.19.04 | 0.19 | 22.2 | 3 | 1/R | 21 |
| | PD | 0 - 70 | 7.19.04 | 0.59 | 15.8 | 3 | Log R | 14 |
| Dead | PA | 18 - 100 | 9.21.04 | 0.59 | 12.0 | 2 | 350 - 1075 nm | 168 |
| | PD | 0 - 40 | 5.25.04 | 0.53 | 7.4 | 2 | 350 - 1075 nm | 93 |
| Exposed | PA | 0 - 18 | 8.24.04 | 0.01 | 1.0 | 1 | 350 - 1075 nm | - |
| | PD | 0 - 40 | 8.24.04 | 0.50 | 11.3 | 1 | $2^{nd}$ derivative | 20 |

The majority of the best models for each species occurred in the latter half of the season (late July to late September) and when that species cover was at a maximum. *P. australis* cover was decreasing in August when its best model was established, but *A. calamus* was at its maximum cover in mid-June when its best model was established (Figure 3.4.27). Best *P. arifolium* PLS models were established in late September at the *Phragmites*-dominant site when *P. arifolium* cover had decreased (Figure 3.4.27) and in August at the *Phragmites*-absent site when *P. arifolium* cover was at a maximum (Figure 3.4.28). Similarly, *P. virginica*'s best models were

established in late May at the *Phragmites*-dominant site when *P. virginica* was at its highest cover of the season (Figure 3.4.27) and in late September at the *Phragmites*-absent site when *P. virginica* was at its lowest cover of the season (Figure 3.4.28). Only *I. capensis* had consistent models for both sites since the best PLS model was established at both sites when *I. capensis* cover was very high (Figures 3.4.27 and 3.4.28).

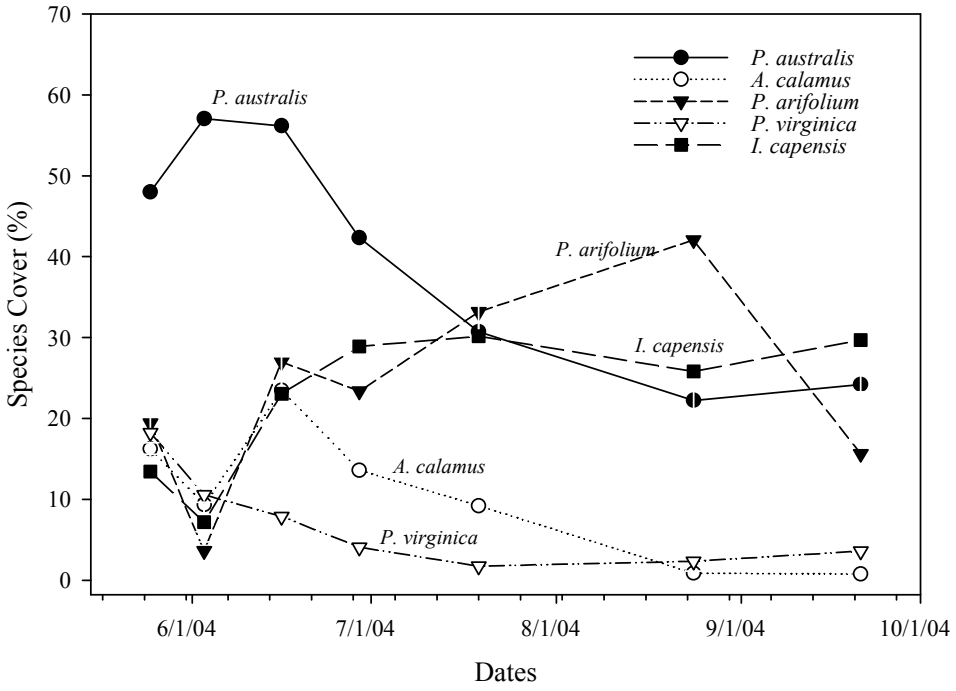



**Figure 3.4.27. Mean species cover for the five most common species present at the *Phragmites*-dominant site during the 2004 growing season.**

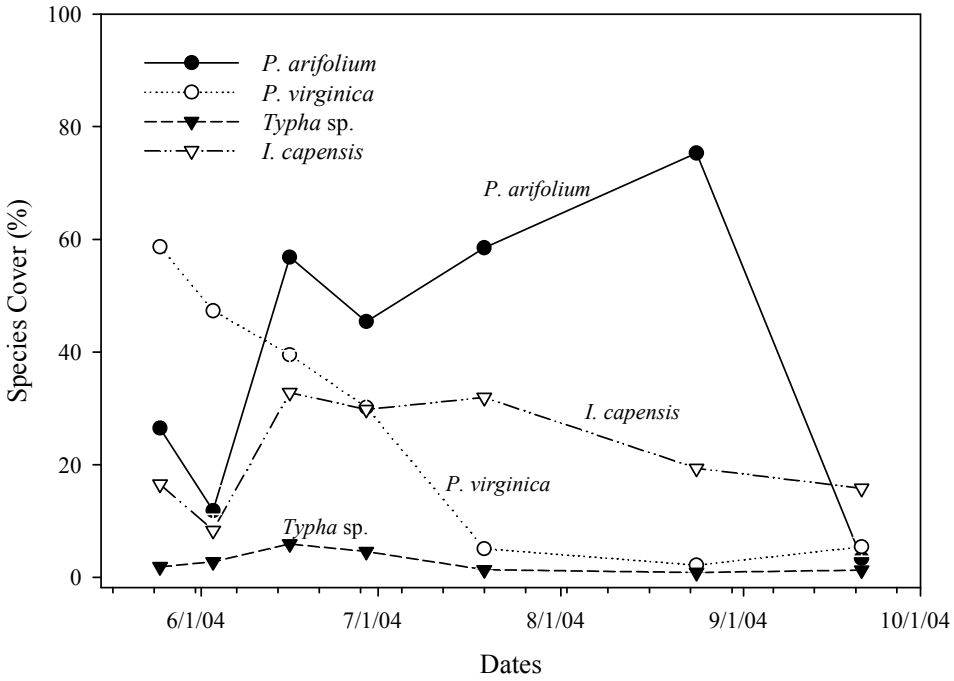



**Figure 3.4.28. Mean species cover for the four most common species present at the *Phragmites*-absent site during the 2004 growing season.**

Several transformations were used to create the best PLS models for the cover of each species. In addition to untransformed reflectance data, 1st and 2nd derivatives, inverse, normalized, and log of the reflectance were used in one or more PLS model (Table 3.4.23). The two cover transformations used in the best PLS models for *A. calamus*, *P. virginica* and *I. capensis* were the square root of the cover and the arcsine of the square root of cover.

Spectral bands used in PLS models for various transformations were compared using plots of regression coefficients. *P. australis* regression models used bands in the blue and red-edge for untransformed reflectance data and the first derivative of the reflectance (Figure 3.4.29a and b). Models using the first derivative of the reflectance

and the first derivative with the log *of P. australis* cover both used green spectral bands, despite the differences in the sample dates between the models (Figure 3.4.29a and c).

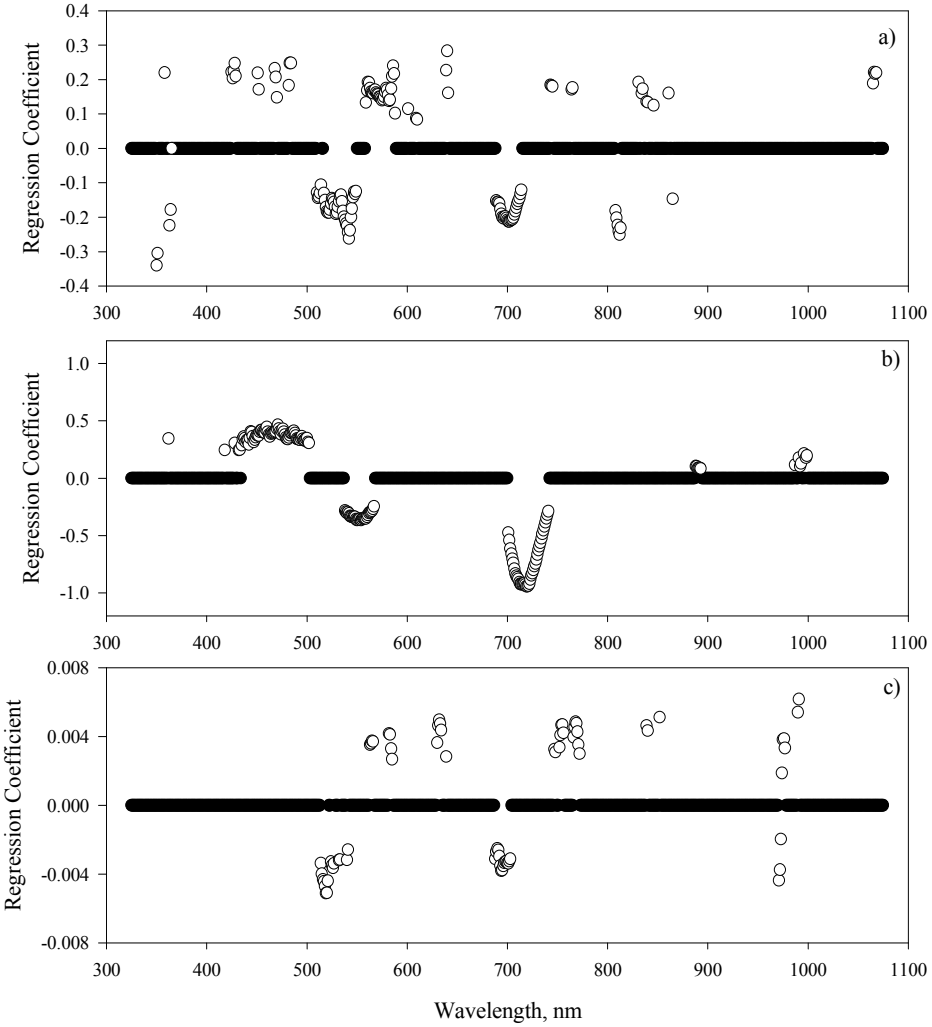



**Figure 3.4.29. PLS regression coefficients for (a) 1st derivative R, *P. australis* 8/02/05 (b) untransformed *P. australis* cover 8/02/05 and (c) 1st derivative R, Log (*P. australis* cover) 8/24/04.**

Regression coefficients for *A. calamus* showed similarities between spectral bands used in PLS models for untransformed data from mid-June, inverse reflectance data for the same sample date, and inverse data with the arcsine of the square root of *A. calamus* (Figure 3.4.30). The models involving the inverse reflectance shared many spectral bands, including bands near 450 nm, 530 nm, 570 nm, 710 nm, and 880 nm

(Figure 3.4.30a and c). All three PLS models shown used spectral bands at 950 nm and 1000 nm (Figure 3.4.30).

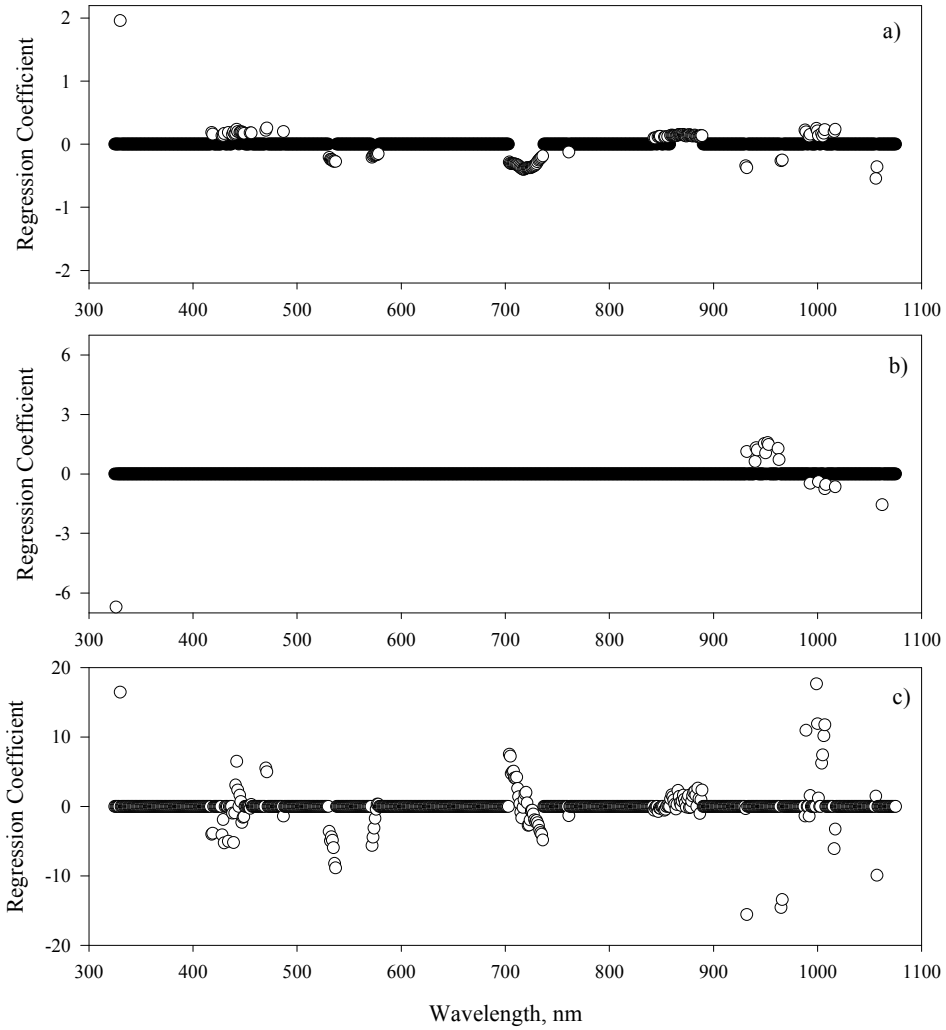



**Figure 3.4.30. PLS regression coefficients for (a) 1/R, *A. calamus* 6/16/04 (b) untransformed *A. calamus* cover 6/16/04 and (c) 1/R, Arcsine Sqrt(*A. calamus* cover) 6/16/04.**

*P. arifolium* regression models using untransformed data from the *Phragmites*-dominant site (8/24/04) and normalized data from the *Phragmites*-absent site (8/24/04) both used spectral bands in the green (Figure 3.4.31b and c), while models of untransformed data from the *Phragmites*-dominant site (9/21/04) and the two sites together (8/24/04) both used spectral bands along the red-edge (Figure 3.4.31a and e).

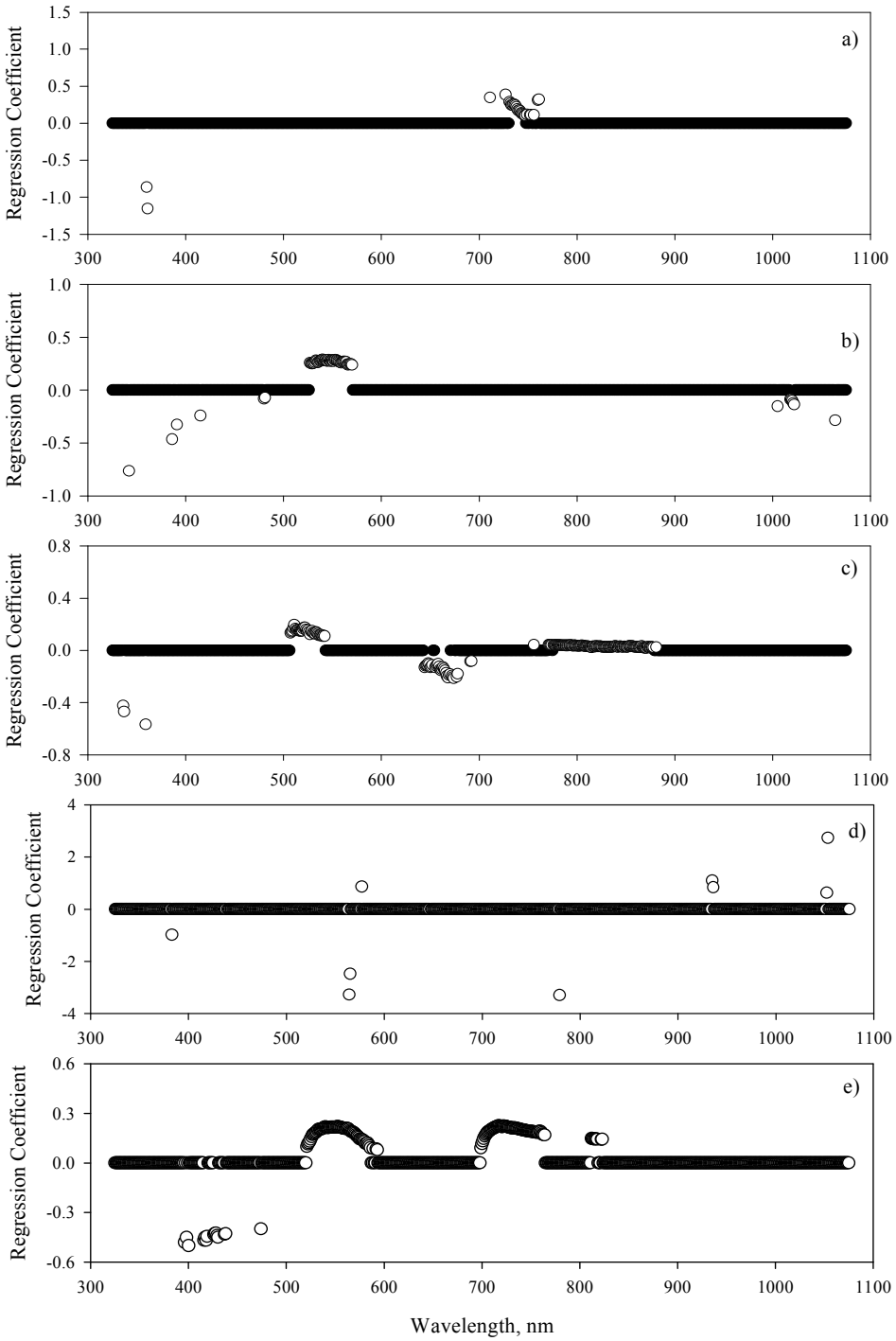



**Figure 3.4.31. PLS regression coefficients for (a) *P. arifolium* cover, *Phragmites*-dominant site, 9/21/04 (b) *P. arifolium* cover, *Phragmites*-dominant site, 8/24/04, (c) Normalized reflectance, *P. arifolium* at the *Phragmites*-absent site, 8/24/04, (d) 2nd golay of the reflectance, *P. arifolium* at the *Phragmites*-absent site, 8/24/04, (e) untransformed *P. arifolium* data for both sites, 8/24/04.**

PLS models at the *Phragmites*-absent site for *P. virginica* in late September used the same spectral bands between 600 – 700 nm and 710 – 810 nm (Figure 3.4.32b and c).

The regression model of truncated data from the *Phragmites*-dominant site shared spectral bands at 630 nm with the *Phragmites*-absent site models (Figure 3.4.32a) and a model of the two sites shared bands in the red-edge with the three other regressions (Figure 3.4.32d).

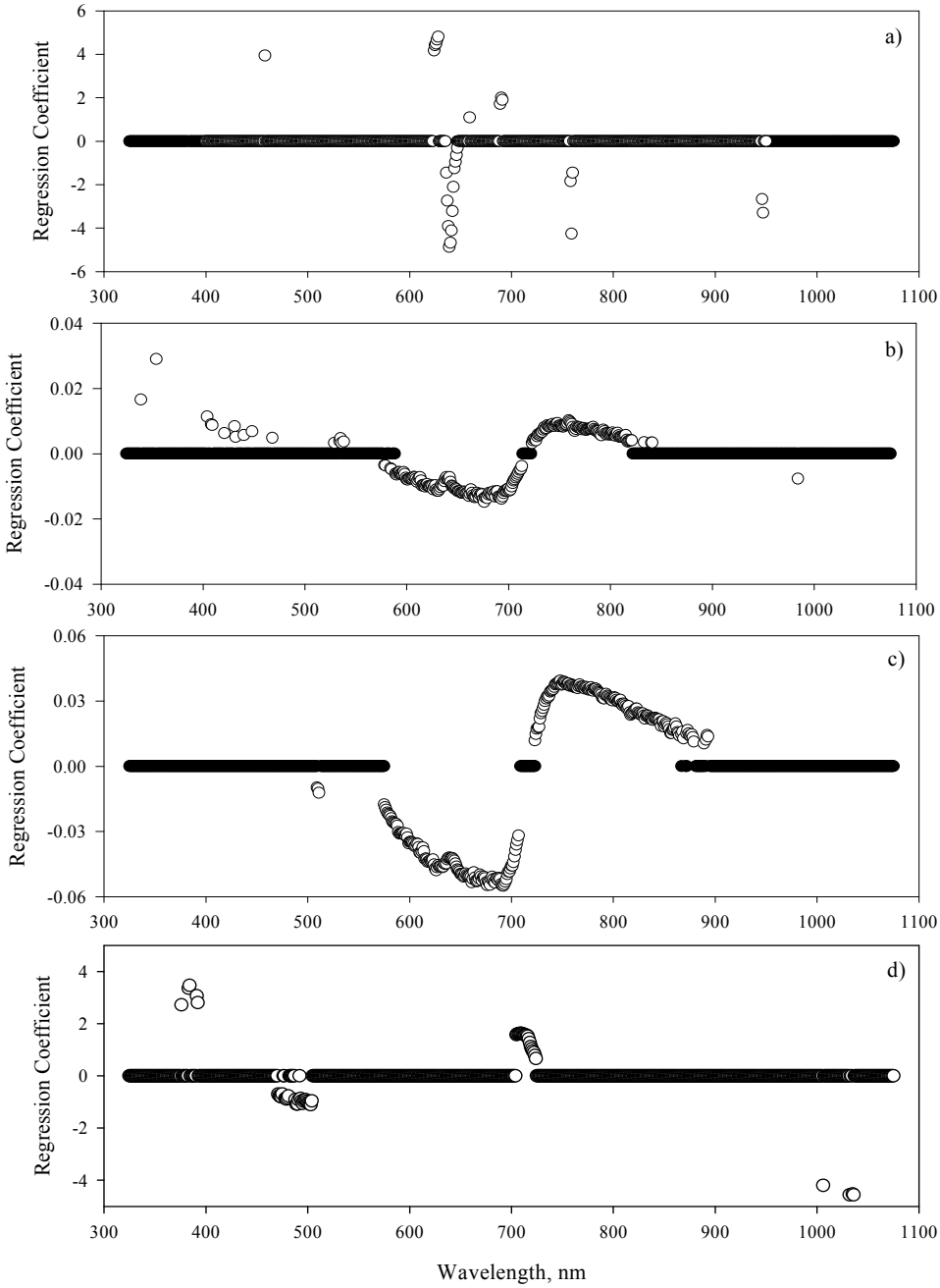



**Figure 3.4.32 PLS regression coefficients for (a) *P. virginica* cover, truncated reflectance from the *Phragmites*-dominant site (5/25/04) (b) Log R, Sqrt (*P. virginica*) 9/21/04, *Phragmites*-absent site, (c) *P. virginica* 9/21/04, *Phragmites*-absent site, (d) combined sites for *P. virginica*, 5/25/04.**

PLS models for *Typha* species had few spectral bands in common (Figure 3.4.33). For two of the best regression models for *Typha* cover, only one band, 580 nm, was used in both (Figure 3.4.33).

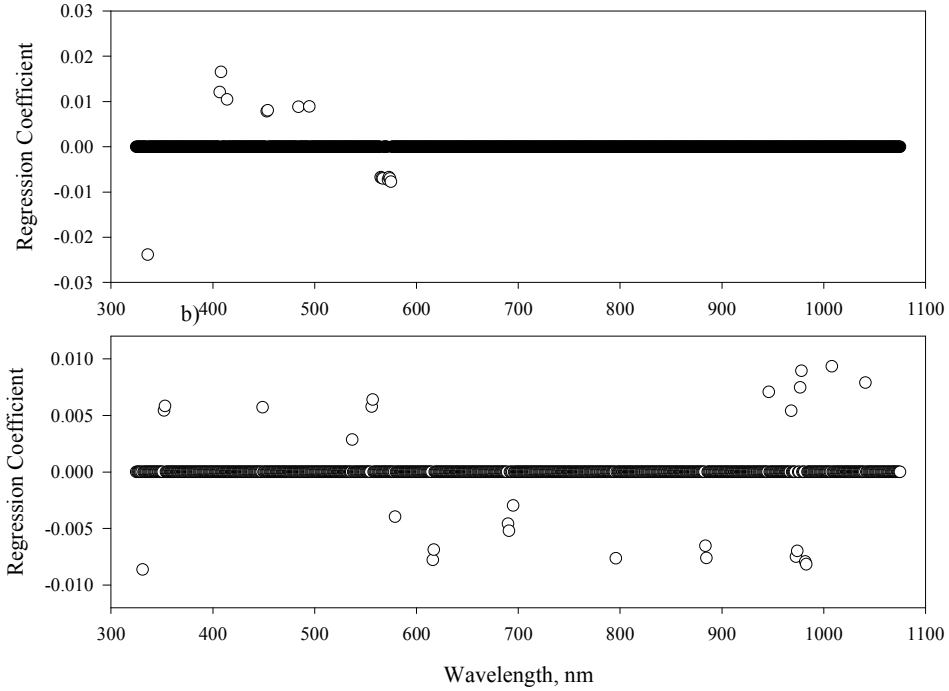



**Figure 3.4.33 PLS regression coefficients for (a) Log R, *Typha* species, 8/24/04 (b) 2nd derivative R, *Typha* sp. 8/24/04**

Regression models of *I. capensis* shared spectral bands near 400 nm and 500 nm, as well as 1000 nm (Figure 3.4.34). In general, more spectral bands were similar between *I. capensis* regression models of the same site.

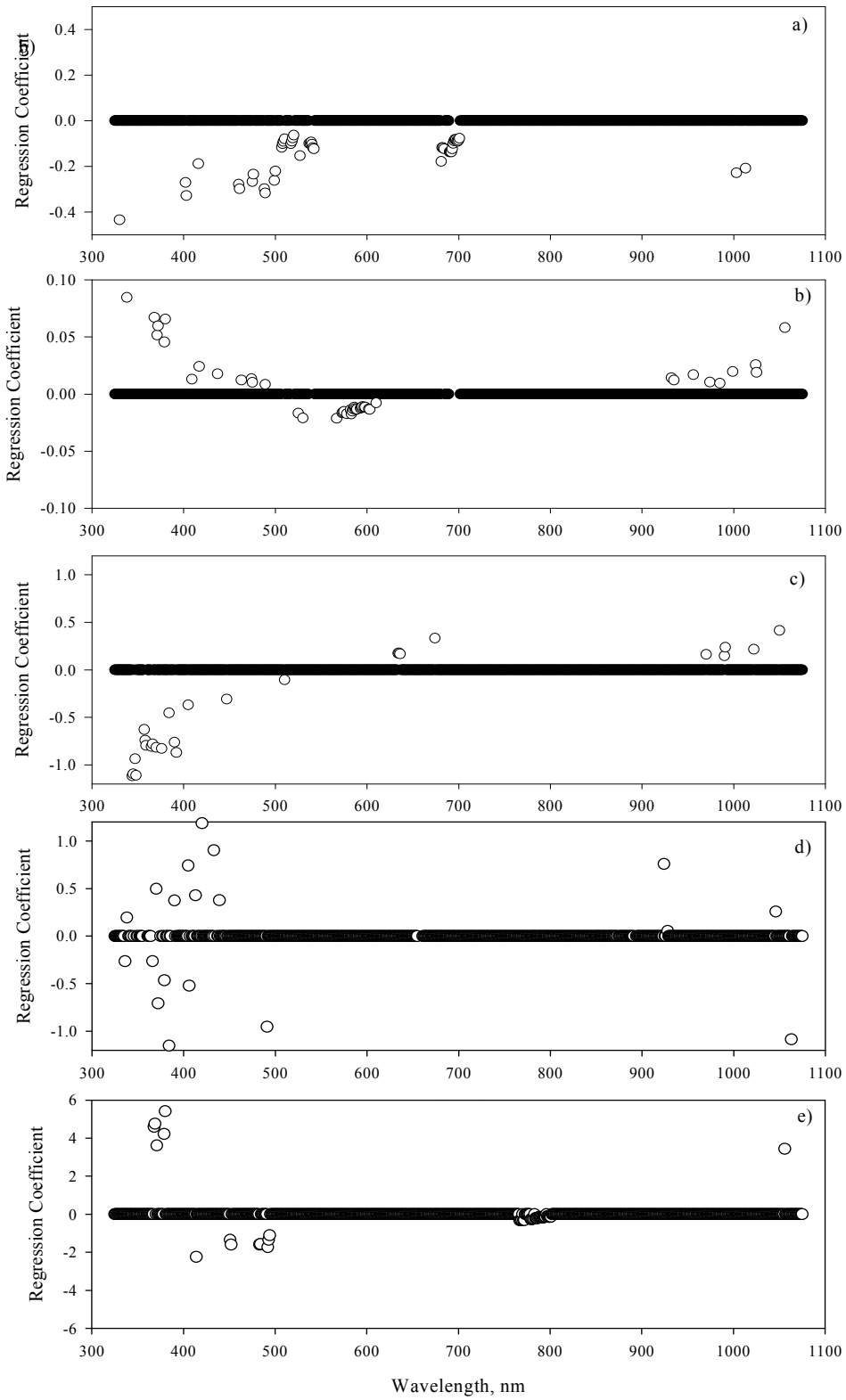



**Figure 3.4.34. PLS regression coefficients for (a) 1st derivative R, *I. capensis*, *Phragmites*-dominant site, 7/19/04, (b) Log R, Sqrt (*I. capensis*), *Phragmites*-dominant site 8/24/04 (c) 1/R, *Phragmites*-absent site, 7/19/04, (d) Log R, *Phragmites*-absent site 7/19/04 (e) untransformed *I. capensis* for both sites, 8/24/04.**

PLS regression models for dead material shared a spectral band at 325 nm, around 650 nm, and at 770 nm (Figure 3.4.35) for models that used the *Phragmites*-dominant site, *Phragmites*-absent site, and combined sites for different sample dates.

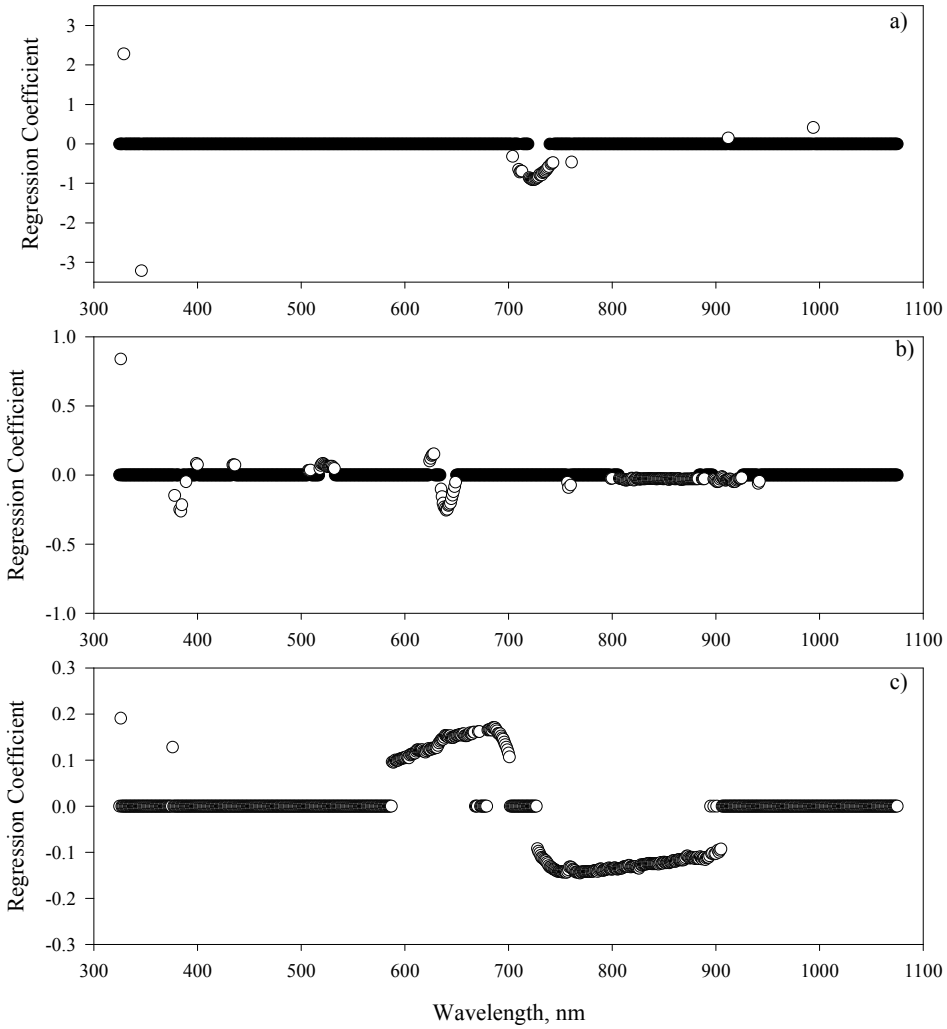



**Figure 3.4.35. PLS regression coefficients for (a) dead material at the *Phragmites*-dominant site on 9/21/04, (b) dead material at the *Phragmites*-absent site on 5/25/04, and (c) dead material at combined sites on 9/21/04.**

Exposed soil regression models for untransformed reflectance at the *Phragmites*-dominant and combined sites used spectral bands at 500 nm and the red-edge (Figure 3.4.36a and c). Models using the 2nd derivative of reflectance at the *Phragmites*-

absent site and reflectance at the *Phragmites*-dominant site shared bands near 590 nm, 710 nm, and 805 nm (Figure 3.4.36a and b).

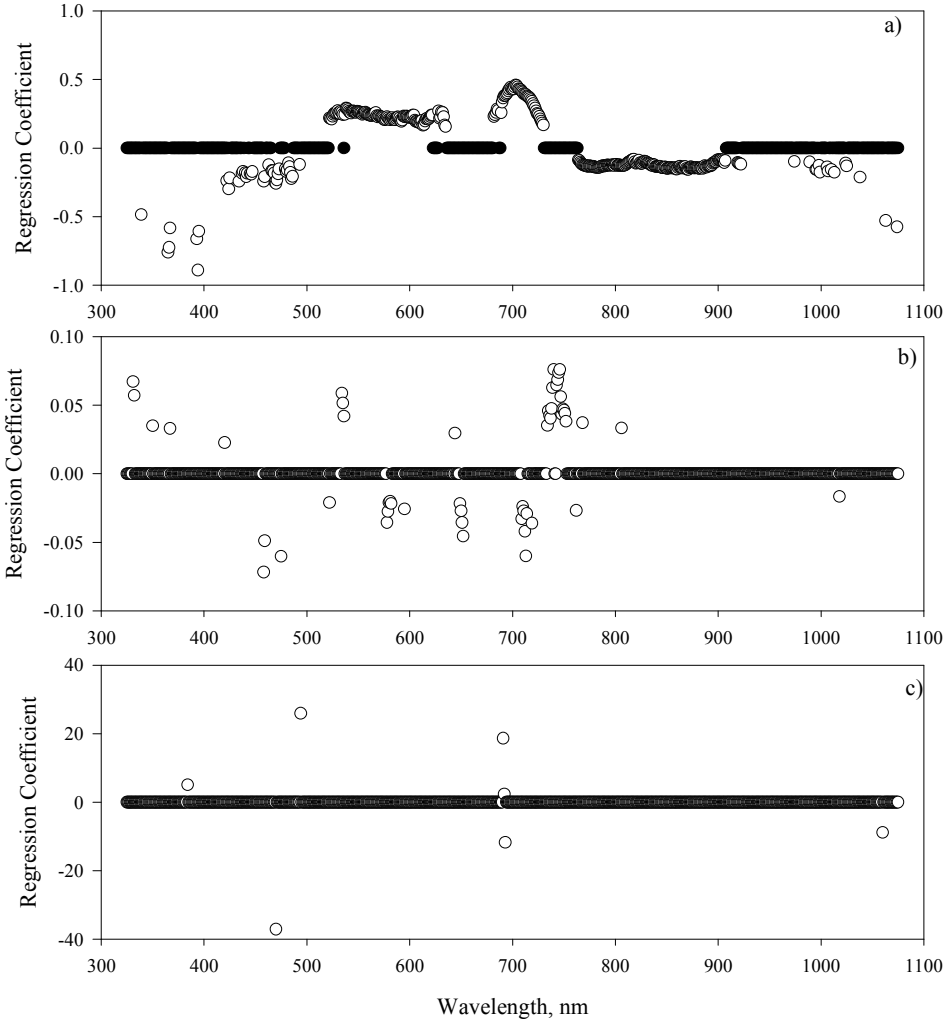



**Figure 3.4.36. PLS regression coefficients for (a) exposed soil at the *Phragmites*-dominant site 8/24/04, (b) 2nd derivative of reflectance at the *Phragmite*s-absent site, 7/19/04, and (c) combined sites on 8/24/04**

It would also be useful to remotely sense marsh characteristics such as leaf area index, species richness and diversity, so we explored the ability of PLS-regression to quantify the characteristics within our study sites using hyperspectral reflectance.

PLS was able to quantify LAI sufficiently at both sites but at different dates during the 2004 growing season. The best LAI model at the *Phragmites*-absent site during August had five PLS-components with an $R^2$ of 0.90 and RMSEP of 1.5, and at the *Phragmites*-dominant site 107 spectral bands combined into ten PLS-components with an $R^2$ of 0.81 and RMSEP of 0.4 during June (Table 3.4.25). Species richness and Shannon-Wiener diversity index, however, were not well predicted with PLS models. The best model for species richness at the *Phragmites*-absent marsh site used nine spectral bands to form one PLS-component with an $R^2$ of 0.31 and RMSEP of 0.8 (Table 3.4.25).

Similar to species cover models, the best vegetation characteristic models did not predict the characteristic well at the opposite marsh site (Table 3.4.26). For example, the PLS model most predictive of LAI at the *Phragmites*-absent site was a poor predictor of LAI at the *Phragmites*-dominant site (Table 3.4.26), although both sites had comparable LAI statistics.

**Table 3.4.25. The best PLS-regression(s) for each vegetation characteristic at individual marsh sites. LAI at the PA site used no spectral bands in its PLS-regression. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands used in the PLS-regression.**

| Species | Site | Range | Date | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|---|---|
| LAI | PD | 4 - 8 | 6.16.04 | 0.81 | 0.4 | 10 | 350 - 1075 nm | 107 |
| | PA | 3 - 7.5 | 8.24.04 | 0.90 | 1.5 | 5 | 350 - 1075 nm | - |
| Sp. Richness | PD | 4 - 10 | 7.19.04 | 0.18 | 1.3 | 2 | 350 - 1075 nm | 420 |
| | PA | 5 - 9 | 6.29.04 | 0.31 | 0.8 | 1 | 350 - 1075 nm | 9 |
| Diversity | PD | 0.5 - 2 | 6.03.04 | 0.46 | 0.2 | 3 | 350 - 1075 nm | 261 |
| | PA | 0.1 - 1.5 | 9.21.04 | 0.71 | 0.3 | 8 | 350 - 1075 nm | 207 |

**Table 3.4.26. The best PLS models of each vegetation characteristic applied to the opposite marsh site. $R^2$ = regression correlation coefficient; RMSEP = root mean square error of prediction; PCs = Partial Least Squares components; # bands used = number of spectral bands used in the PLS-regression.**

| Species | Site | Range | Date | $R^2$ | RMSEP | PCs | Transformation | # bands used |
|---|---|---|---|---|---|---|---|---|
| LAI | PA | 3.5 - 7 | 6.16.04 | 0.01 | 1.0 | 1 | 350 - 1075 nm | - |
| | PD | 3 - 7.5 | 8.24.04 | 0.27 | 1.1 | 6 | 350 - 1075 nm | - |
| Sp. richness | PA | 4 - 11 | 7.19.04 | 0.02 | 1.9 | 1 | 350 - 1075 nm | - |
| | PD | 5 - 10 | 6.29.04 | 0.06 | 1.0 | 6 | 350 - 1075 nm | 3 |
| Diversity | PA | 0.5 - 2 | 6.03.04 | 0.12 | 0.4 | 3 | 350 - 1075 nm | - |
| | PD | 1.2 - 1.9 | 9.21.04 | 0.04 | 0.2 | 1 | 350 - 1075 nm | - |

# Chapter 4: Discussion

### *4.1 Nitrogen fertilization effect on sub-surface marsh N and P levels*

Applying nitrogen as urea to tidal freshwater marshes increases sub-surface marsh nitrogen levels but not phosphorus concentrations. As expected, the highest fertilized treatment yielded the highest concentration of ammonia, nitrate, and total nitrogen for the majority of sample dates, while ambient conditions yielded the lowest concentrations (Figures 3.1.1, 3.1.3, and 3.1.5, respectively). Sub-surface phosphorus concentrations were not affected by nitrogen treatments for either site in the 2004-5 growing seasons.

Contrary to my findings, Harvey et al. (1996) found that mean total nitrogen and total nitrate concentrations in sub-surface water were similar between a high and low treatment of nitrogen fertilizer applied as swine lagoon effluent to Bermuda grass pastures. Leaf nitrogen analyzed in the same experiment, however, found higher leaf nitrogen concentrations in the field with the higher nitrogen application, indicating that the vegetation in the highly fertilized field used the excess nitrogen from the soil and sub-surface water. I found similar results that the addition of nitrogen as fertilizer increased the canopy nitrogen and phosphorus (Figure 3.2.36 – 39).

The fact that sub-surface water nutrients were affected by fertilization in my research implies that nitrification and plant uptake rates could not match the fertilization rate at the *Phragmites*-dominant site. In plots receiving low nitrogen fertilization amounts,

the ammonification of urea, nitrification of ammonia, and plant uptake of nitrate were equally fast, therefore little ammonia and nitrate remained in the sub-surface water. In highly fertilized plots, though, nitrification and plant uptake were presumably less than the application rate, resulting in excess ammonia and nitrate in the sub-surface water.

At the *Phragmites*-absent site, plots receiving both low and high nitrogen fertilization amounts had similar ammonia and nitrate water concentrations, implying that ammonification, nitrification and plant uptake had equal rates and that nitrogen was a limiting factor at the site.

Plots receiving nitrogen as urea in dialysis tubes had a slow-release of nitrogen over the growing season, which was reflected by the constant sub-surface ammonia levels for treatments N200/1D and N200/2D (Figure 3.1.1). Several studies on nitrogen fertilizer released slowly over time have shown an enhancement of crop growth and seed yield (Quiroga-Garza et al. 2001; Kaushal et al. 2005) and a reduction of ammonia volatilization, leaching, and denitrification losses, thereby reducing the nitrogen load on the environment (Rathier and Frink 1989; Quiroga-Garza et al. 2001; Prasad 2005). In contrast, one greenhouse study by Hawkins et al. (2005) found no differences in seedling height, biomass, or nutrient concentration between slow-released and regularly applied nitrogen fertilizer on western hemlock.

### *4.2 Nitrogen fertilization effect on vegetation composition and canopy nutrients*

Nitrogen fertilization affected vegetation composition and canopy nutrient concentrations at both study sites. High nitrogen additions produced a low percent cover in *P. australis*, *P. virginica*, and *Typha* species, while moderate nitrogen additions produced a high percent cover (Figures 3.2.4, 3.2.12, and 3.2.15). Meanwhile, percent cover was high for high nitrogen additions for *A. calamus*, *P. arifolium*, and *I. capensis*, and low for moderate urea additions (Figures 3.2.6, 3.2.8, 3.2.9, 3.2.17, and 3.2.18). Canopy nitrogen and phosphorus concentrations were both high for large additions of nitrogen (Figures 3.2.36 – 39).

The effect of nitrogen on species cover in my study had the ability to change the composition of plant communities. Similar findings of nutrient enrichment to wetlands altering community composition have been reported by Cronk and Fennessy (2001). The Environmental Protection Agency has even proposed that vegetation species composition, percent cover, and spectral greenness be used as indicators of health or ecological integrity of wetlands (Cronk and Fennessey, 2001). Also, some have found nitrogen to decrease the diversity index and increase the dominance of a few species (Cronk and Fennessey, 2001), but my results showed no adverse effects on diversity index or species richness due to nitrogen fertilization (Figures 3.2.23 – 24 and 3.2.29 – 30).

In order to recognize a change in species community composition at a wetland, you must first be familiar with its original composition. In my research, the original

vegetation community compositions between study sites differed significantly. Although close in proximity to one another, the *Phragmites*-dominant site had an abundance of *Phragmites australis* (Figure 3.2.1), while the *Phragmites*-absent site had no *P. australis*, but a lot of *Polygonum arifolium* (Figure 3.2.2). Surprisingly, the *Phragmites*-dominant site had more species and a higher species diversity index than the *Phragmites*-absent site (Figures 3.2.22 and 3.2.28), despite the monoculture tendency of the invasive species, *P. australis*. The vegetation community composition also fluctuated greatly throughout the growing season. At the beginning of the season, *Peltandra virginica* had a high percent cover in both marsh sites, but by mid-summer had given way to *P. arifolium*, *P. australis*, and *I. capensis* (Figure 3.4.27 – 8). By the end of the summer, all species were senescing.

Other research on nitrogen effects on vegetation supported my results that excess nitrogen caused an increase to marsh vegetation biomass (Figures 3.2.31 – 32) (Gibson et al., 1994; Kiehl et al., 1997).

### *4.3 Effects of fertilizer and vegetation on canopy reflectance*

Canopy reflectance of the tidal freshwater marsh was affected by vegetation composition and, to an extent, nitrogen fertilization. Certain individual untransformed spectral bands were affected by the addition of nitrogen (Figure 3.3.18), but more bands were affected by nitrogen when the second derivative of the reflectance curve was used (Figure 3.3.19).

Nitrogen had no effect on the three simple ratios, $R_{493}/R_{678}$, $R_{415}/R_{710}$, and $R_{564}/R_{768}$, and two reflectance indices, PRI and NDVI (Figures 3.3.4 – 13), which was contrary to several other studies. NDVI was successfully correlated to nitrogen treatment in cotton (Bronson et al., 2005), and the indices PRI and RE were used to detect changes in total ammonia in a brackish marsh (Tilley et al., 2003). In a greenhouse experiment on four individual marsh plants, however, indices PRI and NDVI distinguished treatment differences in only two species, *A. calamus* and *P. virginica* (Tilley et al., unpublished). It is possible that the diversity of species in the tidal freshwater marsh prevented a nitrogen effect on reflectance ratios or indices.

Canopy reflectance of the two marsh sites had visually different curves, most likely due to the differences in vegetation at each site (Figure 3.3.14). Each species produced a unique reflectance curve due to morphological differences in the plant. Physical differences between species are easy to detect, for instance *P. australis* has smooth leaves and stem versus the shiny, slick leaves of *P. virginica* and the soft, hairy leaves of *P. arifolium*.

Previous research has also been able to distinguish between vegetation types using reflectance. Several studies have found reflectance in the visible and red-edge capable of identifying weeds from crops (Smith and Blackshaw 2003; Chang et al., 2004; Henry et al., 2004). Individual reflectance signatures were also used successfully to discriminate between salt marsh vegetation communities (Schmidt and Skidmore 2003; Silvestri et al., 2003). Clearly, based on the results of this study and

previous research, vegetation in the wetland affected the reflectance curve of each plot. The differences in species at each site produced significant reflectance distinctions between marsh sites.

### *4.4 Models predictive of nutrient level, vegetation cover, and canopy nutrients*

My analyses indicated that partial least squares (PLS) regression can be used to predict sub-surface water nutrient concentrations and vegetation composition in tidal freshwater marshes.

Partial least squares regression models successfully predicted sub-surface water nutrient concentrations at both tidal freshwater marsh sites. Ammonia concentrations were best estimated with untransformed canopy reflectance from August and September (Tables 3.4.1, 3.4.3, and 3.4.5), which was consistent with the ANOVA analysis, where data from the August and September dates were most affected by nitrogen (Figures 3.1.7 – 8). Sub-surface nitrate concentrations were best estimated in August by PLS regressions (Tables 3.4.7, 3.4.9, and 3.4.11), and total phosphorus concentrations were best predicted in August and September (Tables 3.4.17 and 3.4.19). Total nitrogen concentrations were best predicted in July, when N400 suddenly decreased in concentration (Figure 3.1.5).

In my research, I tested several reflectance transformations in the PLS-regression models. Overall, the transformations that worked consistently well for all water quality data regressions were the first and second derivatives of the reflectance curve with the untransformed water quality data or the logarithm of the water quality

concentration. Other researchers have found the first and second derivative useful for predicting nitrogen in vegetation (Townsend et al., 2003; Petisco et al., 2005).

My results also demonstrated that predictive models of vegetation cover could be developed using PLS regression. The percent cover of *P. australis* was well predicted from canopy reflectance in August ($r^2 = 0.85$), while *A. calamus* showed the best results in June when its percent cover was highest ($r^2 = 0.85$) (Table 3.4.23 *P. arifolium* was well predicted at both the *Phragmites*-absent and *Phragmites*-dominant sites during August when it was the dominant species in the marsh ($r^2 = 0.79$) (Table 3.4.23).

For *P. virginica*, predictive models were best in June at the *Phragmites*-dominant site, when *P. virginica* was at a maximum and in August and September at the *Phragmites*-absent site, when *P. virginica* was at a minimum (Figure 3.2.12 and Table 3.4.23). Although *Typha* species had a cover of 8% or less throughout the growing season, a predictive model was developed using PLS-regressions (Table 3.4.23). The best predictive models of *I. capensis* were in July, which was also the date of peak percent cover of *I. capensis* (Figure 3.2.16). I also found PLS-regression models able to predict the amount of exposed soil and the percent cover of dead material in the marsh, as well as LAI ($r^2 = 0.81$ and 0.90) for both marsh sites (Table 3.4.23 and 3.4.25).

My research agrees with earlier studies and concludes that PLS-regression models are able to predict plant species composition using canopy reflectance data. In previous research, Almeida and De Souza Filho (2004) were able to discriminate between vegetation types in riparian forests, burn grasslands, crops and savannahs using principal component analysis of hyperspectral data. Similarly, Schmidtlein and Sassin (2004) modeled the distribution of plant species in grasslands using high-resolution hyperspectral airborne imagery and PLS-regression. Their model agreed with ground-based observations ($r^2 = 0.71$), but they concluded that distinguishing between plant communities with remote sensing techniques was difficult and needed further development.

Other vegetation components measured in my study did not prove to be as predictable with reflectance data as species cover. I was unable to estimate species richness and species diversity index from the marsh canopy reflectance using PLS-regression. However, in a study by Maestre (2004), species richness and diversity were predicted from reflectance using PLS-regression.

Canopy nitrogen, phosphorus, and biomass were also predicted from canopy reflectance using PLS regressions. The first derivative of the reflectance was the best for predicting canopy nitrogen and biomass, whereas the second derivative of the reflectance was best for canopy phosphorus (Table 3.4.21). Other researchers have agreed with my results. Petisco et al. (2005) predicted the leaf nitrogen, phosphorus, and calcium concentrations in several woody plant species using PLS-regressions,

obtaining an $r^2 = 0.99$ for the best nitrogen prediction model. Bronson et al. (2005) and Fridgen and Varco (2004) both developed predictive models of leaf nitrogen in cotton when it was in peak bloom.

### *4.5 Spectral bands significant to nutrient availability*

Spectral bands offering information on canopy nutrients and nutrient availability were identified using PLS regression and ANOVA. Canopy nitrogen and phosphorus both used spectral bands in the red-edge, while canopy phosphorus also had several significant bands in the visible green.

For sub-surface ammonia concentrations, spectral bands in the visible green and along the red-edge were consistently used in PLS-regressions at both the *Phragmites*-dominant and the *Phragmites*-absent sites. Applied ammonia increases the chlorophyll content of plants, which affects both the visible green and the red-edge. Few studies have investigated chlorophyll's relationship to green reflectance, but several have linked chlorophyll to the red-edge, including work by Fridgen and Varco (2004) and Tarpley et al. (2000) on cotton leaf nitrogen where the red-edge was shifted to longer wavelengths as nitrogen supply increased. Other studies found the red-edge increased significantly with less nitrogen fertilization (Zhao et al., 2003; Zhao et al., 2005).

Nitrate PLS-regressions showed significant spectral bands in the red-edge, like ammonia, and also in the near-infrared. Bands in the near-infrared have been correlated to vegetation biomass and nitrogen uptake (Li et al., 2001). Other research

has shown near-infrared spectral bands able to predict wetland vegetation characteristics (Thenkabail et al. 2000; Becker et al. 2005).

Results from total nitrogen regressions had significant spectral bands in the visible green and along the red-edge. Changes in the visible green spectral bands have been linked to nitrogen deficits in plant leaves (Buscaglia and Varco 2002; Zhao et al., 2003; Zhao et al., 2005). Also, green spectral bands have been identified as optimal bands for characterization of agricultural crops (Thenkabail et al., 2000).

Total phosphorus PLS-regressions showed significant spectral bands concentrated primarily in the near-infrared. Vegetation biomass is closely related to near-infrared reflectance and increases with ample phosphorus (Thenkabail et al., 2000).

### *4.6 Conclusions*

The following conclusions were made from the work contained in this thesis:

1. Nitrogen additions to the tidal freshwater marsh plots increased sub-surface nitrogen levels, biomass in the Phragmites-absent site, and canopy nitrogen and phosphorus, but did not affect sub-surface phosphorus levels, or biomass of the Phragmites-dominant marsh.
2. Applying nitrogen with slow-release dialysis tubes created constant levels of sub-surface nitrogen across the growing season.
3. The percent cover of *P. australis, P. virginica*, and *Typha* species was highest for the middle nitrogen application rate, wheras it was highest for *A. calamus*, *P. arifolium*, and *I. capensis* at the highest nitrogen fertilization rate.

4. Canopy reflectance differed due to vegetation composition.

5. Spectral bands in the red-edge (700 – 730 nm) were useful in vegetation and sub-surface water nutrient predictive models.

6. Models developed using Partial Least Squares regression of hyperspectral canopy reflectance were predictive of sub-surface water nutrient concentrations, vegetation composition, exposed soil, dead material, and canopy nutrients in tidal freshwater marshes.

### *4.7 Implications*

The results of this study suggested that the addition of nitrogen to a tidal freshwater marsh increased the concentration of nitrogen in the sub-surface water, increased the amount of nitrogen and phosphorus stored in the vegetation canopy, increased above ground biomass at the marsh that contained no Phragmites, and altered the vegetation composition. All of these variables influence the canopy reflectance signature, which indicates that hyperspectral radiometry can be used to detect their changes. PLS modeling of hyperspectral canopy reflectance was found to be useful for indirectly detecting the affects of additional nitrogen. In effect the PLS models could estimate canopy nitrogen, above ground biomass, and the cover of dominant species. Reflectance differences caused by nitrogen fertilization, biomass, and vegetation composition, radiometry could be a useful tool for assessing wetlands. That is, hyperspectral radiometry could estimate marsh sub-surface water nitrogen, identify dominant marsh species, assess the percent cover of exposed soil and dead material, and estimate canopy nutrient concentrations.

My results also implied that the species *P. australis*, *P. virginica*, and *Typha* species were not nitrogen – limited, because their percent cover did not continue to increase with the addition of nitrogen. Conversely, *A. calamus*, *P. arifolium*, and *I. capensis* did increase in percent cover with high additions of nitrogen, implying these species were nitrogen – limited in the marsh.

# APPENDIX A List of Abbreviations

| | |
|---|---|
| ANOVA | Analysis of variance |
| LAI | Leaf area index |
| N100 | 100 g – N |
| N200/1D | 200 g – N, 1 dialysis tube |
| N200/2D | 200 g – N, 2 dialysis tubes |
| N400 | 400 g |
| NDVI | $(R_{nir}-R_{red})/(R_{nir}+R_{red})$ |
| $NH_3$ | Ammonia |
| NIR | Near-infrared |
| $NO_3$ | Nitrate |
| PA site | *Phragmites*-absent site |
| PCs | PLS components |
| PD site | *Phragmites*-dominant site |
| PLS | Partial least squares |
| PRI | $(R_{531}-R_{570})/(R_{531}+R_{570})$ |
| R | Correlation coefficient |
| $R^2$ | Coefficient of determination |
| RE | Red edge |
| RMSEP | Root mean square error of prediction |
| TKN | Total nitrogen |
| TP | Total phosphorus |
| VNIR | Visible and near-infrared |

# APPENDIX B Spectral Bands Used in ANOVA and PLS-regressions

**B1. List of significant spectral bands used in PLS regression models for sub-surface water nutrients.**

| $NH_3$ | | | | | | $NH_3$ | $NO_3$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Both sites | $NH_3$ PD site | | | | | PA site | Both sites | $NO_3$ PD site | | | $NO_3$ PA site | | | |
| 511 | 513 | 560 | 704 | 793 | 910 | 492 | 530 | 446 | 533 | 562 | 512 | 697 | 725 | 765 |
| 512 | 514 | 561 | 705 | 794 | 914 | 493 | 538 | 447 | 534 | 563 | 530 | 698 | 729 | 766 |
| 513 | 527 | 562 | 706 | 803 | 915 | 508 | 539 | 448 | 536 | 564 | 531 | 699 | 730 | 767 |
| 514 | 528 | 569 | 707 | 807 | 916 | 509 | 549 | 449 | 537 | 565 | 537 | 700 | 731 | 832 |
| 515 | 529 | 570 | 708 | 808 | 917 | 511 | 550 | 450 | 538 | 566 | 573 | 701 | 732 | 894 |
| 533 | 530 | 573 | 709 | 809 | 918 | 532 | 551 | 496 | 539 | 567 | 574 | 702 | 733 | 895 |
| 534 | 531 | 574 | 710 | 813 | 919 | 547 | 552 | 497 | 540 | 568 | 575 | 703 | 734 | 896 |
| 812 | 532 | 575 | 711 | 814 | 923 | 590 | 553 | 498 | 541 | 569 | 576 | 704 | 735 | |
| 821 | 533 | 578 | 712 | 815 | 924 | 592 | 558 | 499 | 542 | 570 | 577 | 705 | 736 | |
| 824 | 534 | 582 | 713 | 816 | 925 | 601 | 559 | 500 | 543 | 571 | 578 | 706 | 737 | |
| 976 | 535 | 583 | 714 | 822 | 926 | 935 | 560 | 501 | 544 | 572 | 579 | 707 | 738 | |
| | 536 | 584 | 715 | 862 | 927 | | 561 | 510 | 545 | 573 | 580 | 708 | 739 | |
| | 537 | 585 | 716 | 863 | 928 | | 562 | 511 | 546 | 574 | 587 | 709 | 740 | |
| | 538 | 586 | 717 | 864 | 967 | | 563 | 515 | 547 | 576 | 588 | 710 | 741 | |
| | 539 | 599 | 718 | 871 | 1035 | | 564 | 516 | 548 | 577 | 589 | 711 | 742 | |
| | 543 | 606 | 720 | 872 | | | 565 | 517 | 549 | 578 | 597 | 712 | 743 | |
| | 544 | 611 | 729 | 874 | | | 567 | 521 | 550 | 580 | 598 | 713 | 744 | |
| | 545 | 677 | 732 | 875 | | | 573 | 522 | 551 | 602 | 606 | 714 | 745 | |
| | 547 | 682 | 759 | 876 | | | 574 | 523 | 552 | 615 | 607 | 715 | 746 | |
| | 551 | 695 | 760 | 898 | | | 575 | 524 | 553 | 616 | 608 | 716 | 747 | |
| | 552 | 696 | 761 | 899 | | | 576 | 525 | 554 | 617 | 609 | 717 | 748 | |
| | 553 | 697 | 762 | 900 | | | 577 | 526 | 555 | 618 | 610 | 718 | 749 | |
| | 554 | 698 | 787 | 901 | | | 579 | 527 | 556 | 619 | 611 | 719 | 750 | |
| | 555 | 699 | 788 | 903 | | | 580 | 528 | 557 | 620 | 612 | 720 | 751 | |
| | 556 | 700 | 789 | 906 | | | 581 | 529 | 558 | 659 | 689 | 721 | 752 | |
| | 557 | 701 | 790 | 907 | | | 582 | 530 | 559 | 864 | 694 | 722 | 753 | |
| | 558 | 702 | 791 | 908 | | | 584 | 531 | 560 | | 695 | 723 | 763 | |
| | 559 | 703 | 792 | 909 | | | 617 | 532 | 561 | | 696 | 724 | 764 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TKN PD site | | | | | TKN PA site | | | TP PA site | |
| 430 | 489 | 538 | 566 | 712 | 394 | 573 | 684 | 515 | 750 |
| 446 | 493 | 539 | 567 | 713 | 521 | 574 | 700 | 517 | 752 |
| 447 | 494 | 540 | 568 | 714 | 522 | 576 | 702 | 518 | 785 |
| 448 | 495 | 541 | 569 | 715 | 523 | 578 | 703 | 522 | 820 |
| 449 | 496 | 542 | 570 | 716 | 524 | 579 | 704 | 523 | |
| 450 | 497 | 543 | 571 | 717 | 525 | 580 | 705 | 524 | |
| 451 | 499 | 544 | 572 | 718 | 526 | 581 | 706 | 525 | |
| 459 | 500 | 545 | 573 | 719 | 527 | 586 | 707 | 526 | |
| 460 | 501 | 546 | 574 | 720 | 528 | 587 | 708 | 527 | |
| 461 | 518 | 547 | 575 | 721 | 529 | 588 | 709 | 528 | |
| 462 | 519 | 548 | 576 | 722 | 530 | 589 | 710 | 529 | |
| 466 | 520 | 549 | 577 | 723 | 531 | 590 | 711 | 530 | |
| 467 | 521 | 550 | 578 | 724 | 532 | 591 | 712 | 531 | |
| 468 | 522 | 551 | 579 | 725 | 533 | 592 | 713 | 532 | |
| 469 | 523 | 552 | 580 | 726 | 534 | 593 | | 533 | |
| 470 | 524 | 553 | 581 | 727 | 535 | 594 | | 534 | |
| 471 | 525 | 554 | 582 | 728 | 536 | 603 | | 535 | |
| 472 | 526 | 555 | 584 | 729 | 537 | 604 | | 536 | |
| 477 | 527 | 556 | 585 | 730 | 538 | 605 | | 537 | |
| 478 | 528 | 557 | 588 | 731 | 545 | 624 | | 538 | |
| 480 | 529 | 558 | 589 | | 546 | 625 | | 539 | |
| 481 | 530 | 559 | 590 | | 566 | 626 | | 540 | |
| 482 | 532 | 560 | 591 | | 567 | 642 | | 541 | |
| 483 | 533 | 561 | 595 | | 568 | 645 | | 542 | |
| 485 | 534 | 562 | 597 | | 569 | 646 | | 544 | |
| 486 | 535 | 563 | 598 | | 570 | 647 | | 547 | |
| 487 | 536 | 564 | 599 | | 571 | 648 | | 741 | |
| 488 | 537 | 565 | 711 | | 572 | 649 | | 749 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TP PD site | | | | | | | |
| 508 | 582 | 783 | 865 | 902 | 941 | 985 | 1022 |
| 511 | 583 | 793 | 866 | 903 | 945 | 987 | 1023 |
| 512 | 584 | 800 | 867 | 904 | 950 | 988 | 1028 |
| 513 | 585 | 801 | 868 | 905 | 951 | 989 | 1029 |
| 514 | 586 | 802 | 869 | 906 | 952 | 990 | 1030 |
| 515 | 587 | 806 | 870 | 907 | 954 | 991 | 1032 |
| 516 | 588 | 807 | 872 | 908 | 959 | 992 | 1033 |
| 517 | 589 | 808 | 873 | 909 | 960 | 993 | 1036 |
| 518 | 590 | 811 | 874 | 910 | 961 | 994 | 1038 |
| 519 | 591 | 822 | 875 | 911 | 962 | 995 | 1042 |
| 538 | 592 | 825 | 876 | 912 | 963 | 996 | 1043 |
| 549 | 593 | 826 | 877 | 913 | 965 | 997 | 1044 |
| 550 | 594 | 827 | 878 | 915 | 966 | 998 | 1045 |
| 567 | 595 | 828 | 879 | 916 | 967 | 999 | 1050 |
| 568 | 596 | 829 | 880 | 917 | 968 | 1000 | 1051 |
| 569 | 597 | 846 | 881 | 918 | 969 | 1001 | 1052 |
| 570 | 598 | 847 | 882 | 919 | 970 | 1002 | 1055 |
| 571 | 599 | 848 | 883 | 920 | 971 | 1003 | 1060 |
| 572 | 600 | 849 | 884 | 921 | 972 | 1004 | 1069 |
| 573 | 601 | 850 | 885 | 922 | 973 | 1006 | 1073 |
| 574 | 602 | 851 | 886 | 923 | 974 | 1007 | |
| 575 | 603 | 852 | 893 | 924 | 975 | 1008 | |
| 576 | 604 | 853 | 896 | 925 | 976 | 1011 | |
| 577 | 605 | 854 | 897 | 926 | 977 | 1015 | |
| 578 | 606 | 855 | 898 | 930 | 979 | 1017 | |
| 579 | 607 | 862 | 899 | 931 | 980 | 1018 | |
| 580 | 608 | 863 | 900 | 936 | 981 | 1019 | |
| 581 | 615 | 864 | 901 | 938 | 984 | 1021 | |

**B2. List of significant spectral bands determined through PLS regression analysis for vegetation.**

| *P. australis* PD site | | | | *A. calamus* PD site | | | | *P. arifolium* PA site | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 483 | 546 | 574 | 728 | 429 | 706 | 849 | 881 | 432 | 539 | 569 | 607 | 682 | 751 | 808 | 840 | 875 |
| 484 | 547 | 575 | 729 | 430 | 707 | 852 | 882 | 507 | 540 | 570 | 608 | 683 | 752 | 809 | 841 | 876 |
| 500 | 548 | 576 | 730 | 431 | 712 | 853 | 883 | 508 | 541 | 571 | 609 | 684 | 753 | 810 | 842 | 877 |
| 518 | 549 | 577 | 731 | 432 | 718 | 854 | 885 | 509 | 542 | 572 | 610 | 685 | 758 | 811 | 843 | 878 |
| 520 | 550 | 700 | 732 | 438 | 719 | 856 | 886 | 512 | 543 | 573 | 622 | 686 | 775 | 812 | 844 | 881 |
| 521 | 551 | 701 | 733 | 439 | 720 | 857 | 887 | 513 | 544 | 574 | 644 | 687 | 776 | 813 | 845 | 887 |
| 522 | 552 | 702 | 734 | 455 | 721 | 859 | 888 | 514 | 545 | 575 | 645 | 689 | 777 | 814 | 846 | 891 |
| 523 | 553 | 704 | 1002 | 471 | 722 | 860 | 889 | 515 | 546 | 576 | 646 | 691 | 778 | 815 | 847 | 958 |
| 524 | 554 | 705 | | 532 | 723 | 861 | 992 | 517 | 547 | 577 | 647 | 692 | 779 | 816 | 848 | 962 |
| 526 | 555 | 706 | | 533 | 724 | 862 | 993 | 518 | 548 | 578 | 650 | 694 | 781 | 817 | 849 | |
| 527 | 556 | 707 | | 534 | 725 | 863 | 999 | 519 | 549 | 579 | 651 | 709 | 784 | 818 | 850 | |
| 528 | 557 | 708 | | 535 | 726 | 864 | 1000 | 522 | 550 | 584 | 655 | 710 | 785 | 819 | 851 | |
| 529 | 558 | 709 | | 536 | 727 | 865 | 1001 | 523 | 551 | 585 | 656 | 716 | 786 | 820 | 852 | |
| 531 | 559 | 710 | | 537 | 728 | 866 | 1004 | 524 | 552 | 586 | 657 | 717 | 787 | 821 | 853 | |
| 532 | 560 | 711 | | 554 | 729 | 867 | 1007 | 525 | 553 | 587 | 658 | 724 | 788 | 822 | 854 | |
| 533 | 561 | 712 | | 555 | 730 | 868 | 1016 | 526 | 556 | 588 | 659 | 725 | 794 | 825 | 855 | |
| 534 | 562 | 713 | | 556 | 731 | 869 | 1017 | 527 | 557 | 589 | 660 | 726 | 795 | 826 | 856 | |
| 535 | 563 | 714 | | 557 | 732 | 870 | 1056 | 528 | 558 | 590 | 661 | 727 | 796 | 827 | 857 | |
| 536 | 564 | 718 | | 558 | 733 | 871 | 1062 | 529 | 559 | 591 | 665 | 728 | 797 | 828 | 858 | |
| 537 | 565 | 719 | | 559 | 734 | 872 | | 530 | 560 | 592 | 666 | 729 | 798 | 829 | 859 | |
| 538 | 566 | 720 | | 560 | 761 | 873 | | 531 | 561 | 593 | 667 | 730 | 800 | 830 | 860 | |
| 539 | 567 | 721 | | 561 | 762 | 874 | | 532 | 562 | 594 | 668 | 731 | 801 | 832 | 863 | |
| 540 | 568 | 722 | | 562 | 842 | 875 | | 533 | 563 | 595 | 669 | 732 | 802 | 833 | 864 | |
| 541 | 569 | 723 | | 563 | 843 | 876 | | 534 | 564 | 599 | 672 | 733 | 803 | 834 | 865 | |
| 542 | 570 | 724 | | 564 | 844 | 877 | | 535 | 565 | 602 | 673 | 734 | 804 | 835 | 866 | |
| 543 | 571 | 725 | | 574 | 845 | 878 | | 536 | 566 | 603 | 674 | 744 | 805 | 836 | 867 | |
| 544 | 572 | 726 | | 575 | 847 | 879 | | 537 | 567 | 604 | 678 | 748 | 806 | 838 | 868 | |
| 545 | 573 | 727 | | 578 | 848 | 880 | | 538 | 568 | 605 | 679 | 749 | 807 | 839 | 874 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *P. arifolium* PD site | | | | | | | | | | | *P. virginica* PD site | |
| 386 | 543 | 571 | 604 | 714 | 742 | 772 | 800 | 828 | 856 | 990 | 882 | 925 |
| 466 | 544 | 572 | 605 | 715 | 743 | 773 | 801 | 829 | 857 | 991 | 883 | 926 |
| 517 | 545 | 573 | 610 | 716 | 744 | 774 | 802 | 830 | 858 | 993 | 890 | 927 |
| 518 | 546 | 574 | 611 | 717 | 745 | 775 | 803 | 831 | 859 | 994 | 891 | 928 |
| 519 | 547 | 575 | 612 | 718 | 746 | 776 | 804 | 832 | 860 | 1003 | 892 | 929 |
| 520 | 548 | 576 | 613 | 719 | 747 | 777 | 805 | 833 | 861 | 1005 | 893 | 930 |
| 521 | 549 | 577 | 614 | 720 | 748 | 778 | 806 | 834 | 862 | 1006 | 894 | 931 |
| 522 | 550 | 578 | 686 | 721 | 749 | 779 | 807 | 835 | 863 | 1018 | 895 | 964 |
| 523 | 551 | 579 | 691 | 722 | 750 | 780 | 808 | 836 | 864 | 1019 | 896 | 968 |
| 524 | 552 | 580 | 692 | 723 | 751 | 781 | 809 | 837 | 865 | 1020 | 897 | 969 |
| 525 | 553 | 581 | 693 | 724 | 752 | 782 | 810 | 838 | 866 | 1021 | 898 | 970 |
| 526 | 554 | 582 | 694 | 725 | 753 | 783 | 811 | 839 | 867 | 1022 | 900 | 971 |
| 527 | 555 | 583 | 695 | 726 | 754 | 784 | 812 | 840 | 873 | 1023 | 905 | 972 |
| 528 | 556 | 584 | 696 | 727 | 755 | 785 | 813 | 841 | 874 | 1028 | 906 | 973 |
| 529 | 557 | 585 | 697 | 728 | 756 | 786 | 814 | 842 | 888 | | 907 | 974 |
| 530 | 558 | 586 | 698 | 729 | 757 | 787 | 815 | 843 | 889 | | 908 | 975 |
| 531 | 559 | 588 | 699 | 730 | 758 | 788 | 816 | 844 | 899 | | 909 | 987 |
| 532 | 560 | 589 | 703 | 731 | 759 | 789 | 817 | 845 | 900 | | 910 | 988 |
| 533 | 561 | 590 | 704 | 732 | 760 | 790 | 818 | 846 | 912 | | 911 | 1021 |
| 534 | 562 | 591 | 705 | 733 | 761 | 791 | 819 | 847 | 913 | | 912 | 1022 |
| 535 | 563 | 592 | 706 | 734 | 762 | 792 | 820 | 848 | 915 | | 913 | 1028 |
| 536 | 564 | 593 | 707 | 735 | 763 | 793 | 821 | 849 | 916 | | 914 | 1035 |
| 537 | 565 | 596 | 708 | 736 | 764 | 794 | 822 | 850 | 917 | | 916 | 1051 |
| 538 | 566 | 599 | 709 | 737 | 767 | 795 | 823 | 851 | 919 | | 918 | 1054 |
| 539 | 567 | 600 | 710 | 738 | 768 | 796 | 824 | 852 | 920 | | 921 | 1067 |
| 540 | 568 | 601 | 711 | 739 | 769 | 797 | 825 | 853 | 921 | | 922 | |
| 541 | 569 | 602 | 712 | 740 | 770 | 798 | 826 | 854 | 922 | | 923 | |
| 542 | 570 | 603 | 713 | 741 | 771 | 799 | 827 | 855 | 959 | | 924 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *P. virginica* PA site | | | | | | | | | | | | | | | |
| 514 | 545 | 573 | 603 | 659 | 694 | 722 | 750 | 778 | 806 | 834 | 862 | 890 | 918 | 947 | 998 |
| 518 | 546 | 574 | 604 | 660 | 695 | 723 | 751 | 779 | 807 | 835 | 863 | 891 | 919 | 948 | 1000 |
| 519 | 547 | 575 | 605 | 661 | 696 | 724 | 752 | 780 | 808 | 836 | 864 | 892 | 920 | 949 | 1001 |
| 520 | 548 | 576 | 606 | 662 | 697 | 725 | 753 | 781 | 809 | 837 | 865 | 893 | 921 | 950 | 1013 |
| 521 | 549 | 577 | 611 | 663 | 698 | 726 | 754 | 782 | 810 | 838 | 866 | 894 | 922 | 951 | 1022 |
| 522 | 550 | 578 | 612 | 664 | 699 | 727 | 755 | 783 | 811 | 839 | 867 | 895 | 923 | 952 | 1039 |
| 523 | 551 | 579 | 613 | 665 | 700 | 728 | 756 | 784 | 812 | 840 | 868 | 896 | 924 | 953 | |
| 524 | 552 | 580 | 614 | 666 | 701 | 729 | 757 | 785 | 813 | 841 | 869 | 897 | 925 | 954 | |
| 525 | 553 | 581 | 615 | 667 | 702 | 730 | 758 | 786 | 814 | 842 | 870 | 898 | 926 | 955 | |
| 526 | 554 | 582 | 616 | 668 | 703 | 731 | 759 | 787 | 815 | 843 | 871 | 899 | 927 | 956 | |
| 527 | 555 | 583 | 617 | 669 | 704 | 732 | 760 | 788 | 816 | 844 | 872 | 900 | 928 | 957 | |
| 528 | 556 | 584 | 618 | 670 | 705 | 733 | 761 | 789 | 817 | 845 | 873 | 901 | 929 | 958 | |
| 529 | 557 | 585 | 619 | 671 | 706 | 734 | 762 | 790 | 818 | 846 | 874 | 902 | 930 | 961 | |
| 530 | 558 | 586 | 640 | 672 | 707 | 735 | 763 | 791 | 819 | 847 | 875 | 903 | 931 | 965 | |
| 531 | 559 | 587 | 641 | 673 | 708 | 736 | 764 | 792 | 820 | 848 | 876 | 904 | 932 | 966 | |
| 532 | 560 | 588 | 642 | 674 | 709 | 737 | 765 | 793 | 821 | 849 | 877 | 905 | 933 | 967 | |
| 533 | 561 | 589 | 643 | 675 | 710 | 738 | 766 | 794 | 822 | 850 | 878 | 906 | 934 | 968 | |
| 534 | 562 | 590 | 644 | 676 | 711 | 739 | 767 | 795 | 823 | 851 | 879 | 907 | 935 | 969 | |
| 535 | 563 | 591 | 645 | 677 | 712 | 740 | 768 | 796 | 824 | 852 | 880 | 908 | 936 | 970 | |
| 536 | 564 | 592 | 646 | 680 | 713 | 741 | 769 | 797 | 825 | 853 | 881 | 909 | 937 | 971 | |
| 537 | 565 | 593 | 650 | 681 | 714 | 742 | 770 | 798 | 826 | 854 | 882 | 910 | 938 | 978 | |
| 538 | 566 | 594 | 651 | 683 | 715 | 743 | 771 | 799 | 827 | 855 | 883 | 911 | 939 | 979 | |
| 539 | 567 | 595 | 652 | 687 | 716 | 744 | 772 | 800 | 828 | 856 | 884 | 912 | 941 | 980 | |
| 540 | 568 | 598 | 653 | 688 | 717 | 745 | 773 | 801 | 829 | 857 | 885 | 913 | 942 | 984 | |
| 541 | 569 | 599 | 654 | 689 | 718 | 746 | 774 | 802 | 830 | 858 | 886 | 914 | 943 | 987 | |
| 542 | 570 | 600 | 655 | 691 | 719 | 747 | 775 | 803 | 831 | 859 | 887 | 915 | 944 | 988 | |
| 543 | 571 | 601 | 656 | 692 | 720 | 748 | 776 | 804 | 832 | 860 | 888 | 916 | 945 | 989 | |
| 544 | 572 | 602 | 657 | 693 | 721 | 749 | 777 | 805 | 833 | 861 | 889 | 917 | 946 | 997 | |

| | | | | | *I. capensis* | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Typha* species PA site | | | | | PD site | *I. capensis* PA site | | LAI PD site | |
| 400 | 582 | 610 | 717 | 796 | 337 | 339 | 656 | 354 | 612 |
| 401 | 583 | 611 | 718 | 813 | 406 | 344 | 657 | 355 | 613 |
| 408 | 584 | 612 | 719 | 814 | 520 | 347 | 658 | 365 | 614 |
| 414 | 585 | 613 | 720 | 816 | 523 | 348 | 659 | 366 | 615 |
| 424 | 586 | 620 | 721 | 817 | 528 | 356 | 660 | 509 | 616 |
| 430 | 587 | 621 | 722 | 818 | 530 | 357 | 661 | 510 | 617 |
| 453 | 588 | 622 | 723 | 819 | 537 | 358 | 674 | 512 | 618 |
| 454 | 589 | 695 | 724 | 820 | 539 | 359 | | 513 | 619 |
| 463 | 590 | 696 | 725 | 823 | 540 | 360 | | 518 | 620 |
| 464 | 591 | 697 | 726 | 829 | 541 | 365 | | 519 | 621 |
| 484 | 592 | 698 | 727 | 830 | 542 | 366 | | 588 | 622 |
| 495 | 593 | 699 | 728 | 834 | 554 | 368 | | 589 | 638 |
| 496 | 594 | 700 | 729 | | 555 | 370 | | 592 | 640 |
| 566 | 595 | 701 | 730 | | 596 | 371 | | 593 | 641 |
| 567 | 596 | 702 | 731 | | 606 | 374 | | 594 | 651 |
| 569 | 597 | 703 | 732 | | 607 | 376 | | 595 | 652 |
| 570 | 598 | 704 | 733 | | | 384 | | 596 | |
| 571 | 599 | 705 | 734 | | | 390 | | 597 | |
| 572 | 600 | 706 | 735 | | | 392 | | 598 | |
| 573 | 601 | 707 | 736 | | | 405 | | 599 | |
| 574 | 602 | 708 | 737 | | | 447 | | 600 | |
| 575 | 603 | 710 | 738 | | | 448 | | 601 | |
| 576 | 604 | 711 | 739 | | | 449 | | 602 | |
| 577 | 605 | 712 | 740 | | | 460 | | 603 | |
| 578 | 606 | 713 | 748 | | | 619 | | 604 | |
| 579 | 607 | 714 | 749 | | | 653 | | 605 | |
| 580 | 608 | 715 | 776 | | | 654 | | 606 | |
| 581 | 609 | 716 | 777 | | | 655 | | 607 | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAI PA site | | | | | | | | | | | | | |
| 358 | 520 | 549 | 582 | 612 | 677 | 705 | 733 | 761 | 789 | 817 | 845 | 873 | 901 |
| 359 | 521 | 555 | 583 | 613 | 678 | 706 | 734 | 762 | 790 | 818 | 846 | 874 | 902 |
| 362 | 522 | 556 | 584 | 614 | 679 | 707 | 735 | 763 | 791 | 819 | 847 | 875 | 904 |
| 371 | 523 | 557 | 585 | 622 | 680 | 708 | 736 | 764 | 792 | 820 | 848 | 876 | 905 |
| 374 | 525 | 558 | 586 | 639 | 681 | 709 | 737 | 765 | 793 | 821 | 849 | 877 | 908 |
| 387 | 526 | 559 | 587 | 640 | 682 | 710 | 738 | 766 | 794 | 822 | 850 | 878 | 909 |
| 393 | 527 | 560 | 588 | 641 | 683 | 711 | 739 | 767 | 795 | 823 | 851 | 879 | 913 |
| 394 | 528 | 561 | 591 | 642 | 684 | 712 | 740 | 768 | 796 | 824 | 852 | 880 | 914 |
| 408 | 529 | 562 | 592 | 646 | 685 | 713 | 741 | 769 | 797 | 825 | 853 | 881 | 915 |
| 434 | 530 | 563 | 593 | 647 | 686 | 714 | 742 | 770 | 798 | 826 | 854 | 882 | 916 |
| 438 | 531 | 564 | 594 | 652 | 687 | 715 | 743 | 771 | 799 | 827 | 855 | 883 | 923 |
| 502 | 532 | 565 | 595 | 653 | 688 | 716 | 744 | 772 | 800 | 828 | 856 | 884 | 934 |
| 503 | 533 | 566 | 596 | 654 | 689 | 717 | 745 | 773 | 801 | 829 | 857 | 885 | 935 |
| 505 | 534 | 567 | 597 | 656 | 690 | 718 | 746 | 774 | 802 | 830 | 858 | 886 | 936 |
| 506 | 535 | 568 | 598 | 657 | 691 | 719 | 747 | 775 | 803 | 831 | 859 | 887 | 937 |
| 507 | 536 | 569 | 599 | 661 | 692 | 720 | 748 | 776 | 804 | 832 | 860 | 888 | 938 |
| 508 | 537 | 570 | 600 | 662 | 693 | 721 | 749 | 777 | 805 | 833 | 861 | 889 | 939 |
| 509 | 538 | 571 | 601 | 664 | 694 | 722 | 750 | 778 | 806 | 834 | 862 | 890 | 941 |
| 510 | 539 | 572 | 602 | 665 | 695 | 723 | 751 | 779 | 807 | 835 | 863 | 891 | 942 |
| 511 | 540 | 573 | 603 | 666 | 696 | 724 | 752 | 780 | 808 | 836 | 864 | 892 | 943 |
| 512 | 541 | 574 | 604 | 667 | 697 | 725 | 753 | 781 | 809 | 837 | 865 | 893 | 957 |
| 513 | 542 | 575 | 605 | 670 | 698 | 726 | 754 | 782 | 810 | 838 | 866 | 894 | 958 |
| 514 | 543 | 576 | 606 | 671 | 699 | 727 | 755 | 783 | 811 | 839 | 867 | 895 | 1041 |
| 515 | 544 | 577 | 607 | 672 | 700 | 728 | 756 | 784 | 812 | 840 | 868 | 896 | |
| 516 | 545 | 578 | 608 | 673 | 701 | 729 | 757 | 785 | 813 | 841 | 869 | 897 | |
| 517 | 546 | 579 | 609 | 674 | 702 | 730 | 758 | 786 | 814 | 842 | 870 | 898 | |
| 518 | 547 | 580 | 610 | 675 | 703 | 731 | 759 | 787 | 815 | 843 | 871 | 899 | |
| 519 | 548 | 581 | 611 | 676 | 704 | 732 | 760 | 788 | 816 | 844 | 872 | 900 | |

| Species Richness | Percent Dead Material | | | | | | Diversity Index | | | Bare Area | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 706 | 638 | 755 | 784 | 812 | 840 | 868 | 648 | 749 | 830 | 416 | 449 | 486 |
| 707 | 639 | 756 | 785 | 813 | 841 | 869 | 658 | 750 | 831 | 417 | 450 | 490 |
| 708 | 715 | 757 | 786 | 814 | 842 | 870 | 661 | 751 | 841 | 419 | 451 | 491 |
| 1023 | 730 | 758 | 787 | 815 | 843 | 871 | 662 | 752 | 944 | 420 | 452 | 493 |
| | 731 | 760 | 788 | 816 | 844 | 872 | 722 | 753 | 952 | 421 | 453 | 494 |
| | 732 | 761 | 789 | 817 | 845 | 873 | 723 | 754 | 953 | 422 | 454 | 806 |
| | 733 | 762 | 790 | 818 | 846 | 874 | 725 | 755 | 955 | 424 | 455 | 807 |
| | 734 | 763 | 791 | 819 | 847 | 875 | 727 | 756 | 960 | 425 | 456 | 808 |
| | 735 | 764 | 792 | 820 | 848 | 876 | 729 | 757 | 974 | 427 | 457 | 882 |
| | 736 | 765 | 793 | 821 | 849 | 877 | 730 | 758 | 985 | 428 | 458 | 889 |
| | 737 | 766 | 794 | 822 | 850 | 878 | 731 | 761 | 986 | 430 | 459 | 890 |
| | 738 | 767 | 795 | 823 | 851 | 879 | 732 | 766 | 987 | 431 | 463 | 891 |
| | 739 | 768 | 796 | 824 | 852 | 880 | 733 | 767 | 988 | 432 | 466 | |
| | 740 | 769 | 797 | 825 | 853 | 882 | 734 | 768 | 990 | 433 | 467 | |
| | 741 | 770 | 798 | 826 | 854 | 883 | 735 | 769 | 995 | 434 | 468 | |
| | 742 | 771 | 799 | 827 | 855 | 885 | 736 | 775 | 996 | 435 | 469 | |
| | 743 | 772 | 800 | 828 | 856 | 887 | 737 | 778 | 998 | 436 | 470 | |
| | 744 | 773 | 801 | 829 | 857 | 888 | 738 | 779 | 1002 | 437 | 471 | |
| | 745 | 774 | 802 | 830 | 858 | 889 | 739 | 782 | 1013 | 438 | 472 | |
| | 746 | 775 | 803 | 831 | 859 | 891 | 740 | 784 | 1019 | 439 | 473 | |
| | 747 | 776 | 804 | 832 | 860 | 904 | 741 | 785 | | 440 | 475 | |
| | 748 | 777 | 805 | 833 | 861 | 912 | 742 | 786 | | 441 | 476 | |
| | 749 | 778 | 806 | 834 | 862 | 915 | 743 | 791 | | 442 | 479 | |
| | 750 | 779 | 807 | 835 | 863 | 916 | 744 | 794 | | 443 | 480 | |
| | 751 | 780 | 808 | 836 | 864 | 922 | 745 | 801 | | 444 | 481 | |
| | 752 | 781 | 809 | 837 | 865 | 941 | 746 | 806 | | 446 | 483 | |
| | 753 | 782 | 810 | 838 | 866 | 942 | 747 | 809 | | 447 | 484 | |
| | 754 | 783 | 811 | 839 | 867 | | 748 | 813 | | 448 | 485 | |

**B3. List of significant spectral bands identified by an ANOVA model as significantly affected by nitrogen for the second derivative of reflectance (Golay)**

| 6/16/04 *Phragmites*-dominant site | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 415 | 506 | 538 | 569 | 611 | 672 | 703 | 743 | 785 | 895 |
| 442 | 507 | 539 | 572 | 621 | 673 | 704 | 744 | 786 | 896 |
| 448 | 508 | 540 | 573 | 622 | 677 | 705 | 745 | 790 | 897 |
| 453 | 509 | 541 | 574 | 623 | 678 | 706 | 746 | 791 | 903 |
| 454 | 510 | 542 | 575 | 624 | 679 | 707 | 747 | 795 | 914 |
| 455 | 511 | 543 | 576 | 625 | 680 | 708 | 748 | 796 | 919 |
| 456 | 512 | 547 | 577 | 626 | 681 | 709 | 749 | 797 | 920 |
| 457 | 513 | 548 | 578 | 627 | 682 | 710 | 750 | 802 | 921 |
| 458 | 514 | 549 | 579 | 640 | 683 | 711 | 751 | 803 | 928 |
| 467 | 515 | 550 | 580 | 641 | 684 | 712 | 752 | 810 | 929 |
| 468 | 516 | 551 | 581 | 642 | 685 | 713 | 756 | 811 | 934 |
| 478 | 517 | 552 | 582 | 643 | 686 | 714 | 757 | 816 | 941 |
| 479 | 518 | 553 | 583 | 644 | 687 | 718 | 758 | 817 | 946 |
| 485 | 519 | 554 | 584 | 648 | 688 | 719 | 762 | 818 | 975 |
| 489 | 520 | 555 | 590 | 649 | 689 | 720 | 763 | 822 | 976 |
| 490 | 525 | 556 | 591 | 655 | 690 | 721 | 764 | 823 | |
| 491 | 526 | 557 | 592 | 660 | 691 | 722 | 765 | 824 | |
| 492 | 527 | 558 | 593 | 661 | 692 | 723 | 768 | 832 | |
| 493 | 528 | 559 | 594 | 662 | 693 | 733 | 769 | 840 | |
| 494 | 529 | 560 | 597 | 663 | 694 | 734 | 770 | 868 | |
| 495 | 530 | 561 | 603 | 664 | 695 | 735 | 771 | 869 | |
| 499 | 531 | 562 | 604 | 665 | 696 | 736 | 772 | 870 | |
| 500 | 532 | 563 | 605 | 666 | 697 | 737 | 773 | 880 | |
| 501 | 533 | 564 | 606 | 667 | 698 | 738 | 774 | 886 | |
| 502 | 534 | 565 | 607 | 668 | 699 | 739 | 775 | 887 | |
| 503 | 535 | 566 | 608 | 669 | 700 | 740 | 776 | 888 | |
| 504 | 536 | 567 | 609 | 670 | 701 | 741 | 777 | 889 | |
| 505 | 537 | 568 | 610 | 671 | 702 | 742 | 784 | 890 | |

| 6/16/04 *Phragmites* -absent site | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 406 | 506 | 536 | 564 | 603 | 640 | 673 | 701 | 739 | 869 |
| 420 | 507 | 537 | 565 | 604 | 641 | 674 | 702 | 740 | 873 |
| 421 | 508 | 538 | 566 | 605 | 642 | 675 | 703 | 741 | 874 |
| 422 | 509 | 539 | 567 | 606 | 643 | 676 | 704 | 742 | 891 |
| 427 | 510 | 540 | 568 | 607 | 647 | 677 | 705 | 743 | 892 |
| 428 | 511 | 541 | 569 | 608 | 648 | 678 | 706 | 744 | 906 |
| 445 | 512 | 542 | 570 | 609 | 649 | 679 | 707 | 745 | 923 |
| 455 | 513 | 543 | 572 | 610 | 650 | 680 | 708 | 746 | 924 |
| 456 | 514 | 544 | 573 | 613 | 651 | 681 | 709 | 747 | 925 |
| 466 | 515 | 545 | 574 | 618 | 652 | 682 | 710 | 748 | 926 |
| 467 | 516 | 546 | 575 | 619 | 653 | 683 | 711 | 749 | 927 |
| 479 | 517 | 547 | 576 | 620 | 656 | 684 | 712 | 750 | 931 |
| 480 | 518 | 548 | 577 | 621 | 657 | 685 | 713 | 751 | 932 |
| 481 | 519 | 549 | 578 | 622 | 658 | 686 | 714 | 752 | 933 |
| 485 | 520 | 550 | 579 | 623 | 659 | 687 | 725 | 757 | 934 |
| 486 | 521 | 551 | 580 | 624 | 660 | 688 | 726 | 758 | 936 |
| 490 | 524 | 552 | 581 | 625 | 661 | 689 | 727 | 759 | 937 |
| 491 | 525 | 553 | 582 | 627 | 662 | 690 | 728 | 760 | 938 |
| 492 | 526 | 554 | 583 | 628 | 663 | 691 | 729 | 771 | 973 |
| 493 | 527 | 555 | 584 | 629 | 664 | 692 | 730 | 772 | 974 |
| 494 | 528 | 556 | 585 | 630 | 665 | 693 | 731 | 773 | 975 |
| 495 | 529 | 557 | 592 | 631 | 666 | 694 | 732 | 774 | 996 |
| 496 | 530 | 558 | 593 | 632 | 667 | 695 | 733 | 787 | |
| 501 | 531 | 559 | 594 | 633 | 668 | 696 | 734 | 792 | |
| 502 | 532 | 560 | 595 | 636 | 669 | 697 | 735 | 793 | |
| 503 | 533 | 561 | 596 | 637 | 670 | 698 | 736 | 812 | |
| 504 | 534 | 562 | 601 | 638 | 671 | 699 | 737 | 813 | |
| 505 | 535 | 563 | 602 | 639 | 672 | 700 | 738 | 828 | |

| 6/29/04 *Phragmites*-dominant site | | | | | | | | | 6/29/04 *Phragmites*-absent site | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 471 | 534 | 569 | 642 | 693 | 721 | 752 | 815 | 996 | 412 | 513 | 546 | 576 | 621 | 668 | 700 | 734 | 767 | 955 |
| 472 | 535 | 574 | 649 | 694 | 722 | 753 | 816 | | 417 | 514 | 547 | 577 | 622 | 673 | 701 | 735 | 768 | |
| 495 | 536 | 575 | 650 | 695 | 723 | 755 | 817 | | 433 | 515 | 548 | 578 | 623 | 674 | 702 | 736 | 769 | |
| 496 | 537 | 576 | 667 | 696 | 724 | 756 | 825 | | 435 | 516 | 549 | 579 | 624 | 675 | 703 | 737 | 770 | |
| 497 | 538 | 577 | 668 | 697 | 725 | 757 | 826 | | 436 | 517 | 550 | 580 | 625 | 676 | 704 | 738 | 771 | |
| 498 | 539 | 578 | 669 | 698 | 726 | 758 | 827 | | 459 | 518 | 551 | 581 | 626 | 677 | 705 | 739 | 772 | |
| 499 | 540 | 579 | 671 | 699 | 727 | 759 | 830 | | 464 | 519 | 552 | 582 | 627 | 678 | 706 | 740 | 773 | |
| 505 | 541 | 580 | 672 | 700 | 731 | 761 | 831 | | 491 | 520 | 553 | 583 | 635 | 679 | 707 | 741 | 774 | |
| 506 | 547 | 581 | 673 | 701 | 732 | 762 | 832 | | 492 | 525 | 554 | 584 | 636 | 680 | 708 | 742 | 780 | |
| 507 | 550 | 582 | 674 | 702 | 733 | 763 | 862 | | 493 | 526 | 555 | 585 | 637 | 681 | 709 | 743 | 781 | |
| 508 | 551 | 584 | 675 | 703 | 734 | 764 | 863 | | 494 | 527 | 556 | 588 | 638 | 682 | 710 | 744 | 787 | |
| 509 | 552 | 585 | 676 | 704 | 735 | 767 | 889 | | 495 | 528 | 557 | 590 | 639 | 683 | 711 | 745 | 793 | |
| 510 | 553 | 586 | 677 | 705 | 736 | 768 | 890 | | 496 | 529 | 558 | 591 | 640 | 684 | 712 | 746 | 798 | |
| 511 | 554 | 591 | 678 | 706 | 737 | 769 | 894 | | 497 | 530 | 559 | 592 | 641 | 685 | 713 | 747 | 804 | |
| 512 | 555 | 592 | 679 | 707 | 738 | 770 | 895 | | 499 | 531 | 560 | 593 | 642 | 686 | 714 | 748 | 811 | |
| 513 | 556 | 593 | 680 | 708 | 739 | 771 | 896 | | 500 | 532 | 561 | 594 | 643 | 687 | 715 | 749 | 824 | |
| 516 | 557 | 594 | 681 | 709 | 740 | 772 | 901 | | 501 | 533 | 562 | 600 | 647 | 688 | 716 | 750 | 825 | |
| 517 | 558 | 608 | 682 | 710 | 741 | 773 | 903 | | 502 | 534 | 563 | 601 | 648 | 689 | 717 | 751 | 826 | |
| 518 | 559 | 610 | 683 | 711 | 742 | 774 | 904 | | 503 | 535 | 564 | 602 | 649 | 690 | 721 | 752 | 827 | |
| 519 | 560 | 622 | 684 | 712 | 743 | 790 | 905 | | 504 | 536 | 565 | 603 | 650 | 691 | 722 | 753 | 828 | |
| 522 | 561 | 627 | 685 | 713 | 744 | 791 | 920 | | 505 | 537 | 566 | 604 | 651 | 692 | 726 | 754 | 830 | |
| 527 | 562 | 628 | 686 | 714 | 745 | 807 | 936 | | 506 | 538 | 567 | 605 | 652 | 693 | 727 | 755 | 831 | |
| 528 | 563 | 632 | 687 | 715 | 746 | 808 | 966 | | 507 | 539 | 568 | 606 | 661 | 694 | 728 | 756 | 834 | |
| 529 | 564 | 637 | 688 | 716 | 747 | 809 | 972 | | 508 | 540 | 569 | 607 | 662 | 695 | 729 | 757 | 835 | |
| 530 | 565 | 638 | 689 | 717 | 748 | 810 | 977 | | 509 | 541 | 572 | 610 | 663 | 696 | 730 | 761 | 836 | |
| 531 | 566 | 639 | 690 | 718 | 749 | 811 | 986 | | 510 | 542 | 573 | 611 | 665 | 697 | 731 | 762 | 918 | |
| 532 | 567 | 640 | 691 | 719 | 750 | 812 | 987 | | 511 | 543 | 574 | 619 | 666 | 698 | 732 | 763 | 919 | |
| 533 | 568 | 641 | 692 | 720 | 751 | 814 | 990 | | 512 | 545 | 575 | 620 | 667 | 699 | 733 | 766 | 941 | |

| 7/19/04 *Phragmites*-dominant site | | | | | | | | 7/19/04 *Phragmites*-absent site | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 421 | 540 | 579 | 679 | 709 | 745 | 773 | 922 | 413 | 530 | 560 | 594 | 680 | 713 | 751 | 963 |
| 458 | 541 | 580 | 680 | 710 | 746 | 774 | 923 | 414 | 531 | 561 | 595 | 681 | 714 | 756 | 964 |
| 477 | 548 | 581 | 681 | 711 | 747 | 780 | 931 | 417 | 532 | 562 | 600 | 682 | 725 | 757 | |
| 489 | 549 | 582 | 682 | 712 | 748 | 781 | 932 | 418 | 533 | 563 | 601 | 683 | 726 | 758 | |
| 497 | 550 | 583 | 683 | 713 | 749 | 805 | 938 | 422 | 534 | 564 | 604 | 684 | 727 | 762 | |
| 500 | 551 | 585 | 686 | 714 | 750 | 806 | 972 | 452 | 535 | 565 | 620 | 685 | 728 | 763 | |
| 501 | 552 | 592 | 687 | 715 | 751 | 807 | 974 | 497 | 536 | 566 | 621 | 686 | 729 | 764 | |
| 502 | 553 | 593 | 688 | 716 | 752 | 808 | | 502 | 537 | 567 | 622 | 687 | 730 | 768 | |
| 503 | 554 | 594 | 689 | 717 | 753 | 809 | | 503 | 538 | 568 | 623 | 688 | 731 | 769 | |
| 504 | 555 | 595 | 690 | 718 | 754 | 810 | | 504 | 539 | 569 | 624 | 689 | 732 | 770 | |
| 505 | 556 | 600 | 691 | 719 | 755 | 811 | | 505 | 540 | 572 | 637 | 690 | 733 | 771 | |
| 506 | 557 | 601 | 692 | 720 | 756 | 815 | | 506 | 541 | 573 | 638 | 691 | 734 | 772 | |
| 509 | 558 | 610 | 693 | 724 | 757 | 816 | | 507 | 542 | 574 | 639 | 692 | 735 | 773 | |
| 510 | 559 | 620 | 694 | 725 | 758 | 817 | | 508 | 543 | 575 | 640 | 693 | 736 | 857 | |
| 513 | 560 | 622 | 695 | 731 | 759 | 820 | | 509 | 546 | 576 | 641 | 694 | 737 | 858 | |
| 514 | 561 | 623 | 696 | 732 | 760 | 827 | | 510 | 547 | 577 | 642 | 695 | 738 | 861 | |
| 515 | 562 | 624 | 697 | 733 | 761 | 828 | | 511 | 548 | 578 | 650 | 696 | 739 | 862 | |
| 516 | 563 | 625 | 698 | 734 | 762 | 829 | | 512 | 549 | 579 | 651 | 697 | 740 | 872 | |
| 518 | 564 | 626 | 699 | 735 | 763 | 830 | | 513 | 550 | 580 | 652 | 698 | 741 | 879 | |
| 519 | 565 | 636 | 700 | 736 | 764 | 831 | | 514 | 551 | 581 | 667 | 699 | 742 | 896 | |
| 520 | 566 | 641 | 701 | 737 | 765 | 846 | | 515 | 552 | 582 | 670 | 700 | 743 | 902 | |
| 524 | 567 | 642 | 702 | 738 | 766 | 860 | | 516 | 553 | 583 | 671 | 701 | 744 | 903 | |
| 525 | 568 | 643 | 703 | 739 | 767 | 889 | | 520 | 554 | 584 | 672 | 702 | 745 | 916 | |
| 534 | 569 | 650 | 704 | 740 | 768 | 890 | | 525 | 555 | 585 | 674 | 703 | 746 | 917 | |
| 535 | 573 | 654 | 705 | 741 | 769 | 895 | | 526 | 556 | 590 | 675 | 708 | 747 | 918 | |
| 537 | 576 | 672 | 706 | 742 | 770 | 896 | | 527 | 557 | 591 | 676 | 709 | 748 | 935 | |
| 538 | 577 | 677 | 707 | 743 | 771 | 897 | | 528 | 558 | 592 | 678 | 711 | 749 | 936 | |
| 539 | 578 | 678 | 708 | 744 | 772 | 920 | | 529 | 559 | 593 | 679 | 712 | 750 | 941 | |

| 8/24/04 *Phragmites*-dominant site | | | | | 8/24/04 *Phragmites*-absent site | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 492 | 553 | 671 | 704 | 755 | 487 | 519 | 550 | 582 | 625 | 672 | 700 | 748 |
| 494 | 554 | 674 | 705 | 756 | 492 | 520 | 551 | 583 | 636 | 673 | 701 | 749 |
| 504 | 555 | 675 | 706 | 762 | 493 | 524 | 552 | 584 | 637 | 674 | 702 | 750 |
| 505 | 556 | 676 | 707 | 767 | 494 | 525 | 553 | 585 | 638 | 675 | 713 | 751 |
| 509 | 557 | 680 | 708 | 768 | 495 | 526 | 554 | 587 | 639 | 676 | 722 | 752 |
| 510 | 558 | 681 | 709 | 769 | 496 | 527 | 555 | 588 | 640 | 677 | 723 | 756 |
| 512 | 559 | 682 | 710 | 772 | 497 | 528 | 556 | 590 | 641 | 678 | 726 | 761 |
| 513 | 560 | 683 | 718 | 812 | 498 | 529 | 557 | 591 | 642 | 679 | 727 | 762 |
| 521 | 561 | 684 | 733 | 813 | 499 | 530 | 558 | 592 | 645 | 680 | 728 | 767 |
| 527 | 563 | 685 | 734 | 835 | 500 | 531 | 559 | 593 | 647 | 681 | 729 | 768 |
| 528 | 564 | 686 | 735 | 841 | 501 | 532 | 560 | 594 | 648 | 682 | 730 | 769 |
| 529 | 565 | 687 | 736 | 847 | 502 | 533 | 561 | 600 | 649 | 683 | 731 | 807 |
| 530 | 566 | 688 | 737 | 851 | 503 | 534 | 562 | 601 | 650 | 684 | 732 | 808 |
| 531 | 567 | 689 | 738 | 861 | 504 | 535 | 563 | 602 | 651 | 685 | 733 | 809 |
| 532 | 568 | 690 | 739 | 864 | 505 | 536 | 564 | 603 | 652 | 686 | 734 | 815 |
| 533 | 576 | 691 | 740 | 870 | 506 | 537 | 565 | 604 | 655 | 687 | 735 | 821 |
| 534 | 577 | 692 | 741 | 896 | 507 | 538 | 566 | 605 | 656 | 688 | 736 | 822 |
| 535 | 578 | 693 | 742 | 901 | 508 | 539 | 567 | 606 | 657 | 689 | 737 | 823 |
| 536 | 579 | 694 | 743 | 917 | 509 | 540 | 568 | 607 | 658 | 690 | 738 | 831 |
| 537 | 580 | 695 | 744 | 940 | 510 | 541 | 569 | 608 | 663 | 691 | 739 | 832 |
| 541 | 611 | 696 | 745 | 955 | 511 | 542 | 574 | 617 | 664 | 692 | 740 | 891 |
| 542 | 619 | 697 | 746 | | 512 | 543 | 575 | 618 | 665 | 693 | 741 | 899 |
| 546 | 620 | 698 | 747 | | 513 | 544 | 576 | 619 | 666 | 694 | 742 | 924 |
| 547 | 622 | 699 | 748 | | 514 | 545 | 577 | 620 | 667 | 695 | 743 | 956 |
| 549 | 623 | 700 | 749 | | 515 | 546 | 578 | 621 | 668 | 696 | 744 | 961 |
| 550 | 624 | 701 | 750 | | 516 | 547 | 579 | 622 | 669 | 697 | 745 | 965 |
| 551 | 625 | 702 | 751 | | 517 | 548 | 580 | 623 | 670 | 698 | 746 | |
| 552 | 655 | 703 | 752 | | 518 | 549 | 581 | 624 | 671 | 699 | 747 | |

| 9/21/04 *Phragmites*-dominant site | | | | | 9/21/04 *Phragmites*-absent site | | 6/06/05 PD site | 6/06/05 PA site | | 8/02/05 PD site | | 8/02/05 PA site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 410 | 567 | 687 | 745 | 955 | 440 | 803 | 457 | 387 | 1068 | 390 | 822 | 352 |
| 414 | 568 | 688 | 746 | 956 | 531 | 809 | 458 | 389 | 1069 | 470 | 823 | 353 |
| 433 | 569 | 689 | 747 | 957 | 548 | 815 | 478 | 390 | 1071 | 471 | 824 | 354 |
| 442 | 570 | 690 | 748 | 958 | 567 | 816 | 523 | 420 | | 492 | 827 | 452 |
| 500 | 573 | 691 | 749 | 959 | 572 | 863 | 529 | 421 | | 493 | 847 | 524 |
| 501 | 574 | 692 | 750 | 960 | 577 | 885 | 530 | 493 | | 502 | 867 | 629 |
| 502 | 575 | 693 | 751 | 992 | 582 | 886 | 539 | 505 | | 503 | 875 | 648 |
| 503 | 576 | 694 | 768 | 993 | 583 | 983 | 572 | 506 | | 504 | 880 | 670 |
| 504 | 580 | 695 | 769 | | 584 | 1000 | 574 | 545 | | 528 | 929 | 671 |
| 511 | 581 | 696 | 839 | | 623 | | 576 | 546 | | 529 | 930 | 692 |
| 512 | 582 | 697 | 840 | | 624 | | 593 | 587 | | 530 | 934 | 704 |
| 513 | 592 | 698 | 858 | | 682 | | 594 | 860 | | 531 | 936 | 728 |
| 530 | 597 | 699 | 897 | | 683 | | 601 | 861 | | 547 | 988 | 739 |
| 533 | 607 | 700 | 940 | | 684 | | 602 | 862 | | 581 | 996 | 766 |
| 534 | 608 | 701 | 941 | | 685 | | 629 | 901 | | 640 | 1038 | 767 |
| 535 | 667 | 728 | 942 | | 686 | | 787 | 926 | | 644 | 1046 | 790 |
| 536 | 675 | 729 | 943 | | 687 | | 793 | 936 | | 645 | 1048 | 791 |
| 548 | 676 | 730 | 944 | | 688 | | 794 | 940 | | 654 | | 822 |
| 549 | 677 | 734 | 945 | | 689 | | 838 | 941 | | 656 | | 823 |
| 550 | 678 | 735 | 946 | | 690 | | 846 | 966 | | 697 | | 827 |
| 551 | 679 | 736 | 947 | | 711 | | | 967 | | 698 | | 865 |
| 557 | 680 | 738 | 948 | | 727 | | | 985 | | 726 | | 866 |
| 558 | 681 | 739 | 949 | | 728 | | | 986 | | 727 | | 896 |
| 559 | 682 | 740 | 950 | | 729 | | | 1033 | | 728 | | 902 |
| 560 | 683 | 741 | 951 | | 735 | | | 1034 | | 736 | | 907 |
| 561 | 684 | 742 | 952 | | 736 | | | 1035 | | 763 | | 966 |
| 565 | 685 | 743 | 953 | | 737 | | | 1064 | | 764 | | |
| 566 | 686 | 744 | 954 | | 797 | | | 1067 | | 795 | | |

| *Phragmites*-dominant site summary | | | | | | *Phragmites*-absent site summary | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 500 | 540 | 576 | 682 | 710 | 755 | 492 | 527 | 556 | 590 | 648 | 688 | 732 | 773 |
| 501 | 541 | 577 | 683 | 711 | 756 | 493 | 528 | 557 | 591 | 649 | 689 | 733 | |
| 502 | 547 | 578 | 684 | 712 | 757 | 494 | 529 | 558 | 592 | 650 | 690 | 734 | |
| 503 | 548 | 579 | 685 | 713 | 758 | 495 | 530 | 559 | 593 | 651 | 691 | 735 | |
| 504 | 549 | 580 | 686 | 714 | 762 | 496 | 531 | 560 | 594 | 652 | 692 | 736 | |
| 505 | 550 | 581 | 687 | 718 | 763 | 497 | 532 | 561 | 600 | 663 | 693 | 737 | |
| 506 | 551 | 582 | 688 | 719 | 764 | 501 | 533 | 562 | 601 | 665 | 694 | 738 | |
| 509 | 552 | 592 | 689 | 720 | 767 | 502 | 534 | 563 | 602 | 666 | 695 | 739 | |
| 510 | 553 | 593 | 690 | 733 | 768 | 503 | 535 | 564 | 603 | 667 | 696 | 740 | |
| 511 | 554 | 594 | 691 | 734 | 769 | 504 | 536 | 565 | 604 | 668 | 697 | 741 | |
| 512 | 555 | 608 | 692 | 735 | 770 | 505 | 537 | 566 | 605 | 670 | 698 | 742 | |
| 513 | 556 | 610 | 693 | 736 | 771 | 506 | 538 | 567 | 606 | 671 | 699 | 743 | |
| 516 | 557 | 622 | 694 | 737 | 772 | 507 | 539 | 568 | 607 | 672 | 700 | 744 | |
| 518 | 558 | 623 | 695 | 738 | 773 | 508 | 540 | 569 | 619 | 673 | 701 | 745 | |
| 519 | 559 | 624 | 696 | 739 | 774 | 509 | 541 | 572 | 620 | 674 | 702 | 746 | |
| 527 | 560 | 625 | 697 | 740 | 810 | 510 | 542 | 573 | 621 | 675 | 703 | 747 | |
| 528 | 561 | 641 | 698 | 741 | 811 | 511 | 543 | 574 | 622 | 676 | 708 | 748 | |
| 529 | 562 | 642 | 699 | 742 | 816 | 512 | 545 | 575 | 623 | 677 | 709 | 749 | |
| 530 | 563 | 667 | 700 | 743 | 817 | 513 | 546 | 576 | 624 | 678 | 711 | 750 | |
| 531 | 564 | 671 | 701 | 744 | 889 | 514 | 547 | 577 | 625 | 679 | 712 | 751 | |
| 532 | 565 | 672 | 702 | 745 | 890 | 515 | 548 | 578 | 636 | 680 | 713 | 752 | |
| 533 | 566 | 675 | 703 | 746 | 895 | 516 | 549 | 579 | 637 | 681 | 714 | 756 | |
| 534 | 567 | 676 | 704 | 747 | 896 | 517 | 550 | 580 | 638 | 682 | 726 | 757 | |
| 535 | 568 | 677 | 705 | 748 | 897 | 518 | 551 | 581 | 639 | 683 | 727 | 762 | |
| 536 | 569 | 678 | 706 | 749 | 920 | 519 | 552 | 582 | 640 | 684 | 728 | 768 | |
| 537 | 573 | 679 | 707 | 750 | | 520 | 553 | 583 | 641 | 685 | 729 | 769 | |
| 538 | 574 | 680 | 708 | 751 | | 525 | 554 | 584 | 642 | 686 | 730 | 771 | |
| 539 | 575 | 681 | 709 | 752 | | 526 | 555 | 585 | 647 | 687 | 731 | 772 | |

**Table C1. PLS-regressions for *P. australis* percent cover at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *P. australis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Norris 1st Derivative | none | 8.02.05 | 0.92 | 12.03 | 15 | none | 3 | 142 | none |
| Untransformed (350-1075nm) | none | 8.02.05 | 0.87 | 15.81 | 15 | none | 3 | 157 | none |
| Golay 2nd Derivative, avg 10 | none | 8.02.05 | 0.86 | 16.12 | 15 | none | 2 | 13 | none |
| Norris 1st Derivative | Log PHAU | 8.24.04 | 0.83 | 0.28 | 14 | Plot 6 | 3 | 70 | Plot 6: high reflectance |
| Truncated spectra (400-950nm) | none | 8.24.04 | 0.81 | 13.82 | 14 | Plot 6 | 5 | 20 | Plot 6: high reflectance |
| Untransformed (350-1075nm) | none | 6.06.05 | 0.79 | 16.09 | 15 | none | 3 | 213 | none |
| Untransformed (350-1075nm) | Square root PHAU | 8.24.04 | 0.79 | 1.55 | 15 | none | 5 | 24 | none |
| Untransformed (350-1075nm) | Log (base 10) PHAU | 8.24.04 | 0.79 | 0.32 | 15 | none | 4 | 36 | none |
| Norris 1st Derivative | none | 8.24.04 | 0.79 | 14.39 | 14 | Plot 6 | 2 | 52 | Plot 6: high reflectance |
| Untransformed (350-1075nm) | none | 5.25.04 | 0.78 | 10.47 | 14 | Plot 6 | 6 | 40 | Plot 10: high *Phagmites* concentration |
| Untransformed (350-1075nm) | 4th root PHAU | 8.24.04 | 0.78 | 0.38 | 15 | none | 4 | 37 | none |
| Golay 2nd Derivative, avg 10 | Log PHAU | 8.24.04 | 0.77 | 0.33 | 15 | none | 1 | 53 | none |
| MSC Transformation | none | 8.24.04 | 0.75 | 15.69 | 15 | none | 3 | 21 | none |
| Log R | Square root PHAU | 7.19.04 | 0.73 | 1.44 | 13 | Plots 5, 10 | 5 | 387 | Plot 5: high reflectance; Plot 10: low reflectance |
| Log R | Square root PHAU | 8.24.04 | 0.72 | 1.79 | 15 | none | 5 | 231 | none |
| Golay 1st Derivative | none | 8.24.04 | 0.71 | 16.75 | 15 | Plot 6 | 1 | 84 | Plot 6: high reflectance |
| Golay 2nd Derivative, avg 10 | none | 8.24.04 | 0.71 | 16.20 | 15 | none | 1 | 27 | none |
| Absorbance Transformation | none | 8.24.04 | 0.71 | 16.59 | 15 | none | 3 | 12 | none |
| Untransformed (350-1075nm) | none | 6.16.04 | 0.69 | 14.87 | 15 | none | 3 | 42 | none |
| Untransformed (350-1075nm) | Arcsine sqrt (PHAU) | 8.24.04 | 0.63 | 0.22 | 14 | Plot 6 | 4 | 136 | Plot 6: high reflectance |
| Untransformed (350-1075nm) | none | 8.24.04 | 0.60 | 19.67 | 14 | Plot 6 | 4 | 110 | Plot 6: high reflectance |
| Untransformed (350-1075nm) | none | 6.03.04 | 0.57 | 21.25 | 14 | Plot 3 | 3 | 115 | Plot 3: high reflectance |

| Spectra Transformations | *P. australis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **none** | 8.24.04 | 0.56 | 19.25 | 15 | none | 3 | 125 | none |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.54 | 19.27 | 13 | Plots 5,10 | 1 | 33 | Plot 5: high reflectance; Plot 10: low reflectance |
| **Transform 1/R** | **Arcsine sqrt (PHAU)** | 8.24.04 | 0.53 | 0.25 | 15 | none | 3 | 156 | none |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.53 | 19.97 | 15 | none | 3 | 162 | none |
| **Golay 2nd Derivative, avg 10** | **Log PHAU** | 7.19.04 | 0.52 | 0.31 | 15 | none | 1 | 32 | none |
| **Transform 1/R** | **none** | 8.24.04 | 0.52 | 19.97 | 15 | none | 3 | 126 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.49 | 20.00 | 13 | Plots 5,10 | 1 | 113 | Plot 5: high reflectance; Plot 10: low reflectance |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.49 | 20.14 | 13 | Plots 5,10 | 1 | 129 | Plot 5: high reflectance; Plot 10: low reflectance |
| **Transform 1/R** | **none** | 7.19.05 | 0.49 | 20.71 | 13 | Plots 5,10 | 7 | none | Plot 5: high reflectance; Plot 10: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.48 | 20.16 | 13 | Plots 2,11 | 3 | 123 | Plot 2: high reflectance; Plot 11: high *Phragmites* conc. |
| **Manual test set** | **none** | 8.24.04 | 0.42 | 22.07 | 5 | Plot 6 | 2 | none | Plot 6: high reflectance; Remainder used in calib. |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.41 | 22.48 | 15 | none | 2 | 8 | none |
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.35 | 21.29 | 15 | none | 2 | 11 | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.32 | 22.37 | 15 | none | 1 | 23 | none |
| **Random test set** | **none** | 8.24.04 | 0.01 | 24.18 | 5 | none | 1 | none | Remainder used for calibration |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | -0.24 | 25.42 | 15 | none | 1 | none | none |

**Table C2. PLS-regression transformations tested on *P. australis* percent cover at the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (PHAU) | 4th root PHAU | Sqrt (PHAU) | $Log_{10}$ PHAU | Manual test set | Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (PHAU) | Log R | Log R, Sqrt (PHAU) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | X | | | | | | | | | | | | |
| 6/3/2004 | X | | | | | | | | | | | | |
| 6/16/2004 | X | | | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | | | |
| 7/19/2004 | X | X | | | | | | | | X | | | X |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | | | | | | | | | | | | |
| 6/6/2005 | X | | | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Deriv, Log (PHAU) | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (PHAU) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | | |
| 6/3/2004 | | | | | | | | |
| 6/16/2004 | | | | | | | | |
| 6/29/2004 | | | | | | | | |
| 7/19/2004 | X | | X | X | X | | | |
| 8/24/2004 | X | X | X | X | X | X | X | X |
| 9/21/2004 | | | | | | | | |
| 6/6/2005 | | | | | | | | |
| 8/2/2005 | X | | | X | | | | |

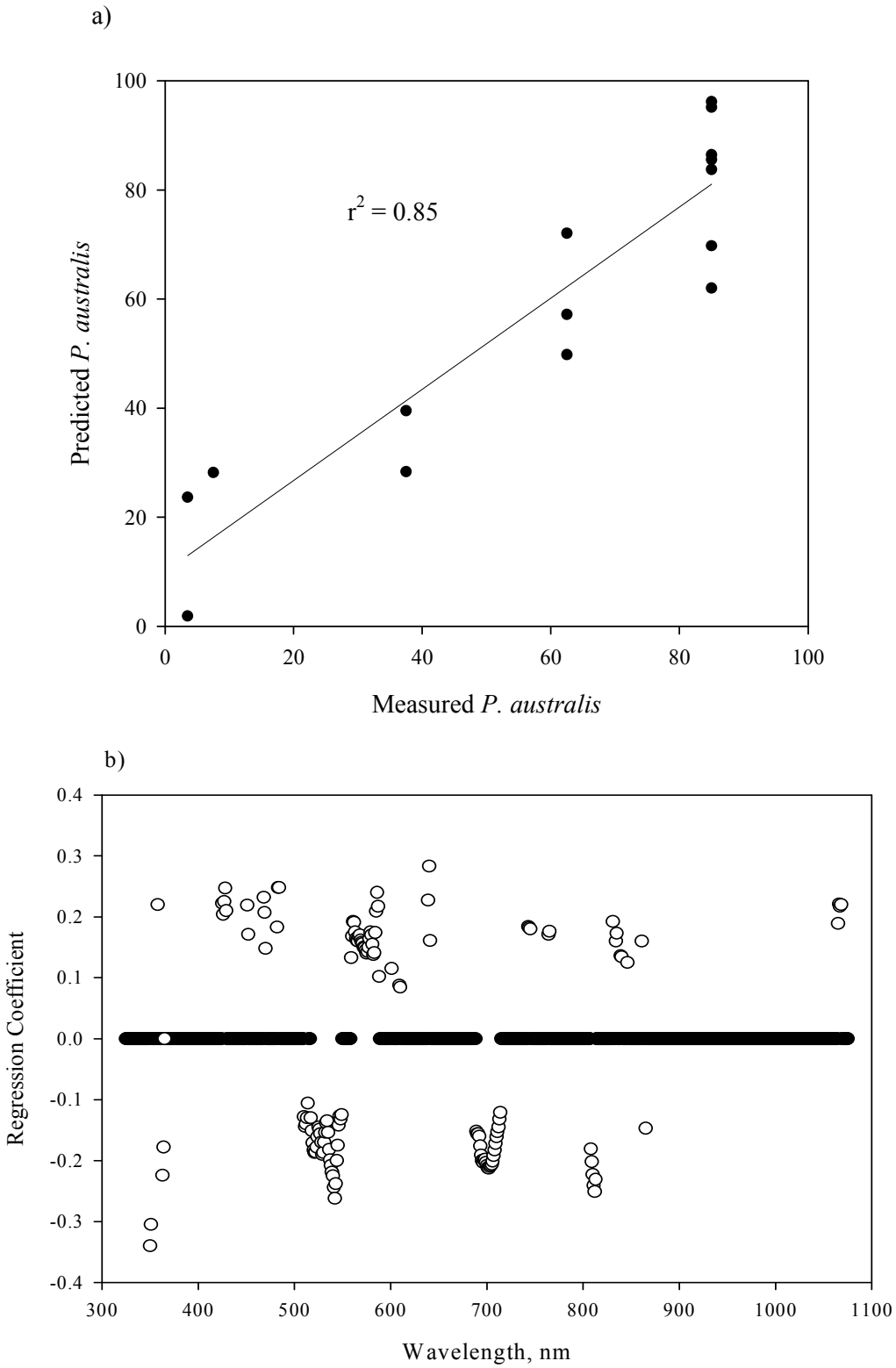



**Figure C1. (a) Predicted vs measured *P. australis* PLS-regression at the *Phragmites*-dominant site, 8/02/05 data, which used 142 spectral bands of first derivative reflectance that were combined into three PLS-components with r = 0.92 and RMSEP = 12%. (b) Loading plot of regression coefficients for the PLS-regression where significant spectral bands used in the regression are depicted by open circles.**

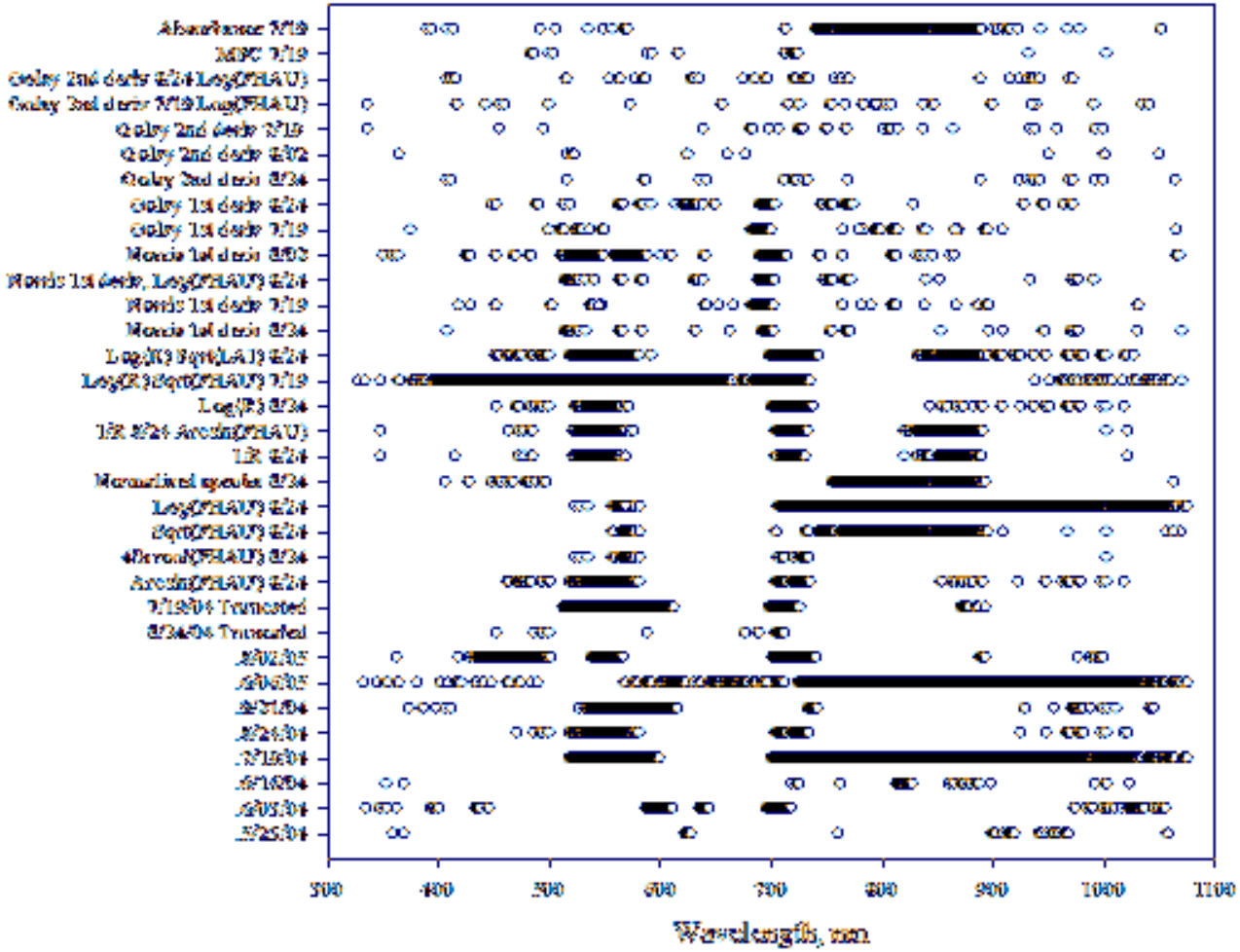



**Figure C2. Significant spectral bands for *P. australis* according to PLS-regressions at the *Phragmites*-dominant site.**

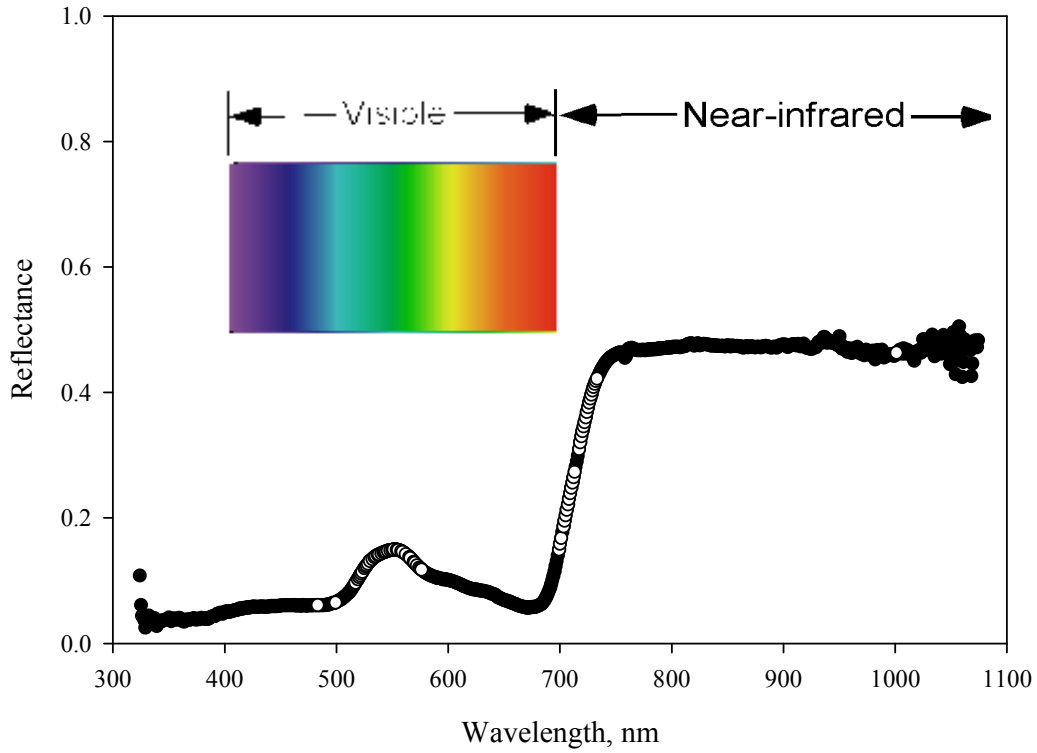



**Figure C3. Spectral bands significant for ten or more regressions for *P. australis* at the *Phragmites*-dominant site are indicated by an open circle.**

**Table C3. PLS-regressions for *A. calamus* cover (%) at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *A. calamus* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Transform 1/R** | **none** | 6.16.04 | 0.92 | 6.78 | 15 | none | 8 | 128 | none |
| **Transform 1/R** | **Arcsine sqrt (ACCA)** | 6.16.04 | 0.92 | 6.78 | 15 | none | 8 | 128 | none |
| **Kubelka-Munk Transformation** | **none** | 6.16.04 | 0.81 | 9.95 | 15 | none | 4 | 121 | none |
| **Norris 1st Derivative** | **none** | 6.16.04 | 0.80 | 10.33 | 15 | none | 1 | 11 | none |
| **Golay 2nd Derivative, avg 10** | **Log ACCA** | 6.16.04 | 0.79 | 0.33 | 15 | none | 1 | 62 | none |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.77 | 10.76 | 15 | none | 5 | 17 | none |
| **Untransformed (350-1075nm)** | **4th root ACCA** | 6.16.04 | 0.75 | 0.08 | 13 | Plots 3,5 | 6 | 24 | Plots 3,5: no *A. calamus* in plot |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (ACCA)** | 6.16.04 | 0.74 | 0.17 | 15 | none | 4 | 35 | none |
| **MSC Transformation** | **none** | 6.16.04 | 0.73 | 11.71 | 15 | none | 4 | 11 | none |
| **Log R** | **none** | 6.16.04 | 0.72 | 11.87 | 15 | none | 3 | 177 | none |
| **Absorbance Transformation** | **none** | 6.16.04 | 0.72 | 11.83 | 15 | none | 3 | 175 | none |
| **Untransformed (350-1075nm)** | **Square root ACCA** | 6.16.04 | 0.71 | 1.54 | 15 | none | 4 | 34 | none |
| **Log R** | **Square root ACCA** | 6.16.04 | 0.71 | 1.61 | 15 | none | 3 | 115 | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.68 | 0.87 | 14 | Plot 6 | 3 | 82 | Plot 6: high reflectance |
| **Golay 1st Derivative** | **none** | 6.16.04 | 0.67 | 12.63 | 15 | none | 1 | 57 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.67 | 9.15 | 14 | Plot 5 | 2 | 38 | Plot 5: high reflectance |
| **Norris 1st Derivative** | **none** | 6.29.04 | 0.63 | 12.90 | 14 | Plot 4 | 2 | 79 | Plot 4: high reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 6.29.04 | 0.63 | 13.06 | 14 | Plot 4 | 1 | 17 | Plot 4: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.62 | 9.19 | 12 | Plots 1-3 | 2 | 115 | Plots 1-3: missing reflectance |
| **Untransformed (350-1075nm)** | **Log (base 10) ACCA** | 6.16.04 | 0.58 | 0.44 | 15 | none | 4 | 16 | none |

| Spectra Transformations | *A. calamus* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Golay 2nd Derivative, avg 10** | **none** | 6.16.04 | 0.58 | 14.85 | 15 | none | 1 | 36 | none |
| **Truncated spectra (400-950nm)** | **none** | 6.16.04 | 0.55 | 15.90 | 14 | Plot 9 | 3 | 155 | Plot 9: high reflectance |
| **Golay 1st Derivative** | **none** | 6.29.04 | 0.53 | 14.13 | 14 | Plot 4 | 1 | 10 | Plot 4: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.50 | 13.67 | 15 | none | 2 | 316 | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.50 | 14.38 | 14 | Plot 4 | 3 | 10 | Plot 4: high reflectance |
| **Transform 1/R** | **none** | 6.29.04 | 0.15 | 17.11 | 14 | Plot 4 | 1 | none | Plot 4: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.15 | 2.02 | 14 | Plot 11 | 1 | none | Plot 11: low reflectance |
| **Truncated spectra (400-950nm)** | **none** | 6.29.04 | 0.14 | 17.28 | 14 | Plot 4 | 2 | none | Plot 4: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.10 | 6.36 | 12 | Plots 1-3 | 1 | none | Plots 1-3: high reflectance |
| **Log R** | **Square root ACCA** | 6.29.04 | 0.07 | 2.09 | 14 | Plot 4 | 1 | none | Plot 4: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.20 | 0.76 | 15 | none | 1 | none | none |

**Table C4. PLS-regression transformations tested on spectrum and *A. calamus* percent cover at the *Phragmites*-dominant site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (ACCA) | 4th root ACCA | Sqrt (ACCA) | $Log_{10}$ ACCA | Transform 1/R | Transform 1/R, Arcsine sqrt (ACCA) | Log R | Log R, Sqrt (ACCA) |
|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | X | | | | | | | | | |
| 6/3/2004 | X | | | | | | | | | |
| 6/16/2004 | X | X | X | X | X | X | X | X | X | X |
| 6/29/2004 | X | X | | | | | X | | | X |
| 7/19/2004 | X | | | | | | | | | |
| 8/24/2004 | X | | | | | | | | | |
| 9/21/2004 | X | | | | | | | | | |
| 6/6/2005 | X | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | |

| | Norris 1st Derivative | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (ACCA) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | |
| 6/3/2004 | | | | | | | |
| 6/16/2004 | X | X | X | X | X | X | X |
| 6/29/2004 | X | X | X | | | | |
| 7/19/2004 | | | | | | | |
| 8/24/2004 | | | | | | | |
| 9/21/2004 | | | | | | | |
| 6/6/2005 | | | | | | | |
| 8/2/2005 | | | | | | | |

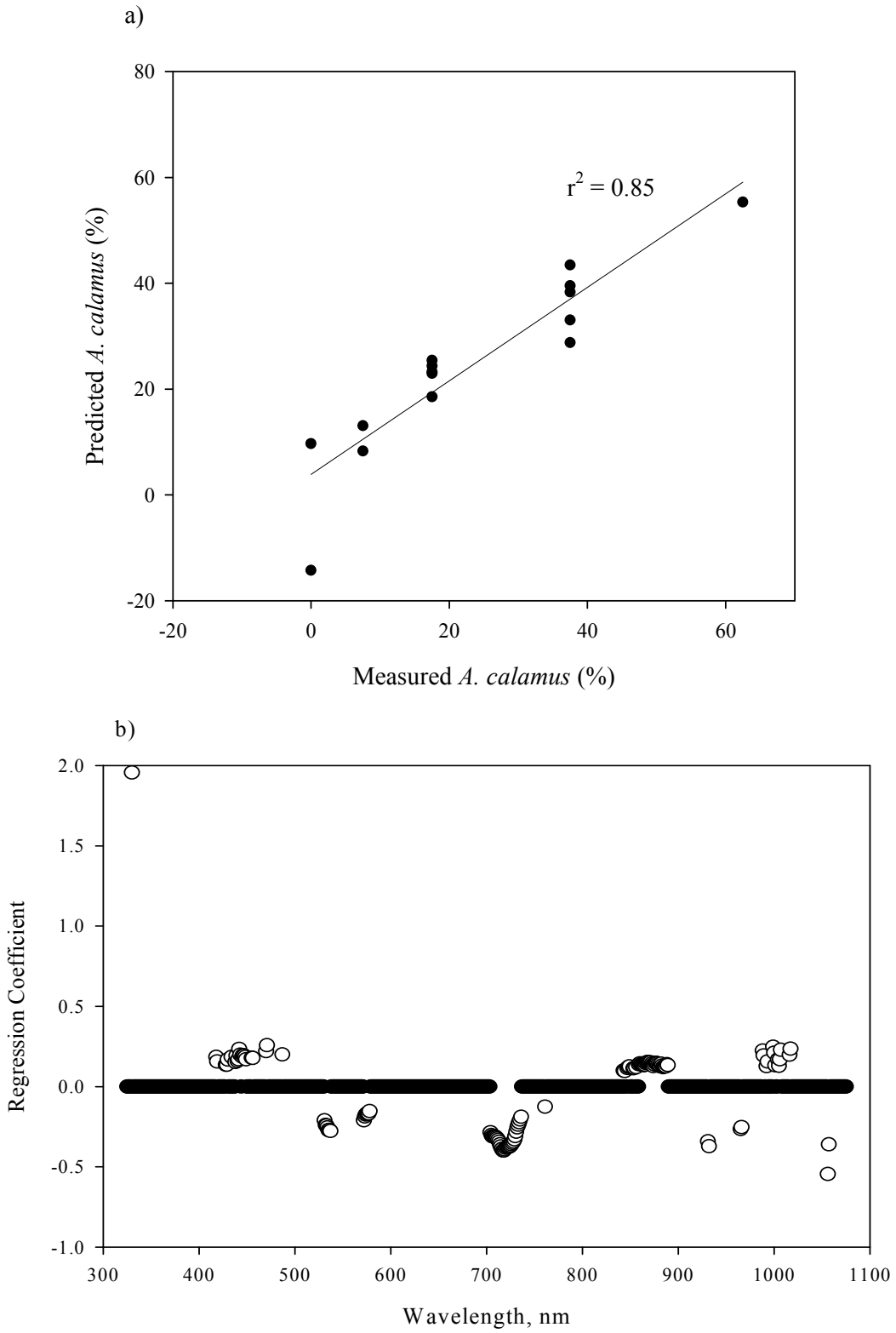



**Figure C4. (a) Predicted vs measured *A. calamus* cover (%) PLS-regression of the inverse reflectance for the *Phragmites*-dominant site, 6/16/04 data, which used 128 spectral bands that were combined into eight PLS-components with r = 0.92 and RMSEP of 6.8%. (b) Loading plot of regression coefficients, where spectral bands used in the regression are depicted by open circles.**

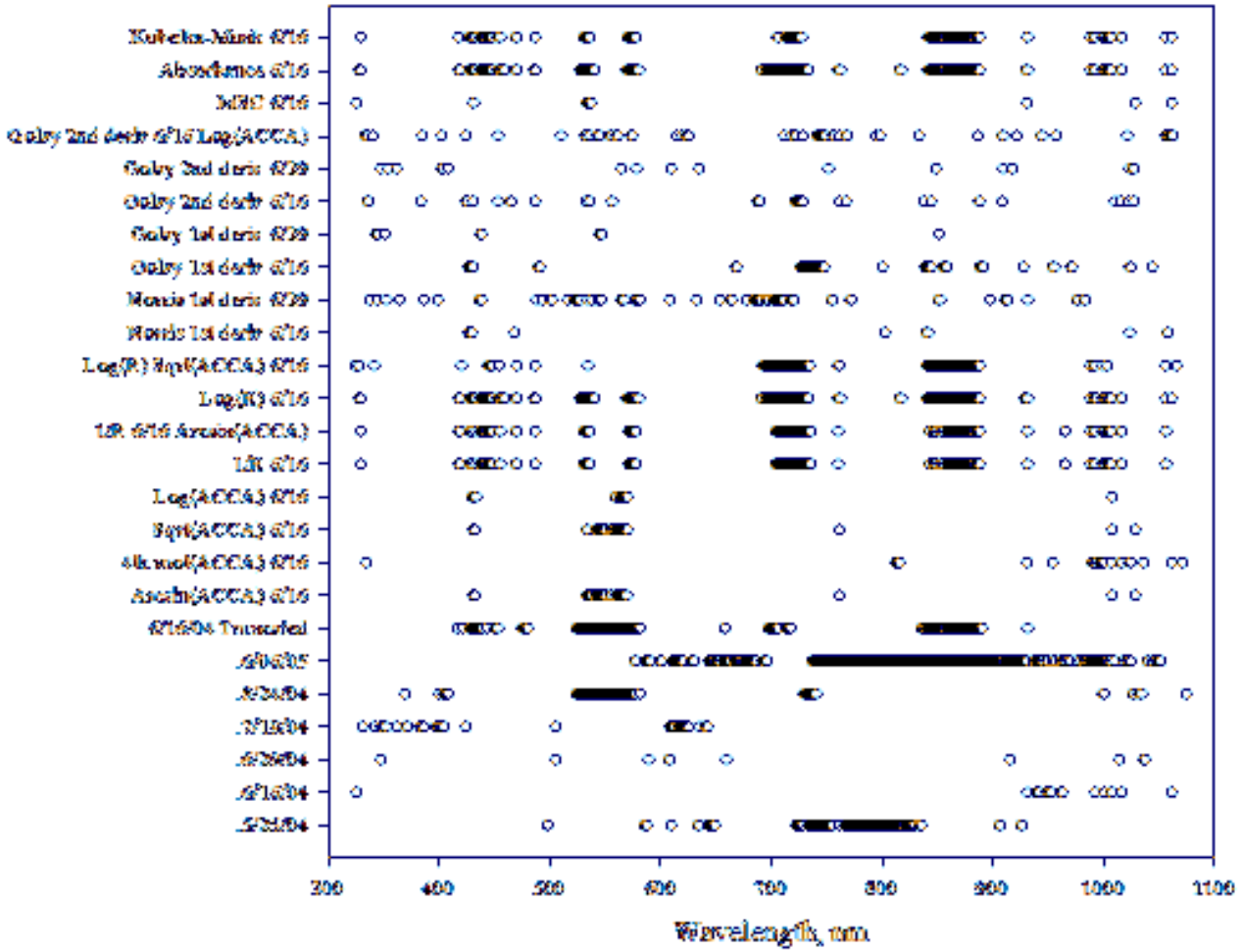



**Figure C5. Significant spectral bands for *A. calamus* according to PLS-regressions at the *Phragmites*-dominant site.**

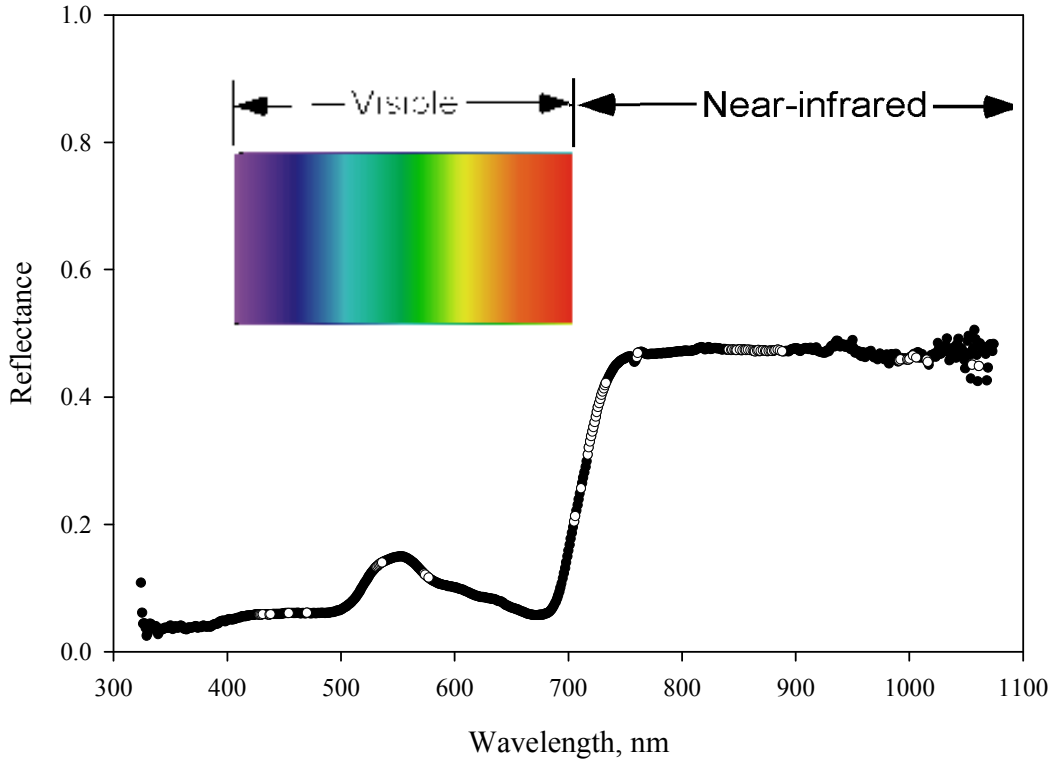



**Figure C6. Spectral bands significant for seven or more regressions for *A calamus* cover at the *Phragmites*-dominant site are indicated by an open circle.**

**Table C5. PLS-regressions for *P. arifolium* cover (%) at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *P. arifolium* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.86 | 8.87 | 15 | none | 3 | 27 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.83 | 15.24 | 15 | none | 1 | 76 | none |
| **Norris 1st Derivative** | **none** | 9.21.04 | 0.83 | 9.37 | 15 | none | 4 | 49 | none |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.81 | 9.97 | 15 | none | 7 | 36 | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.80 | 16.40 | 15 | none | 3 | 59 | none |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (POAR)** | 8.24.04 | 0.78 | 0.20 | 15 | none | 3 | 100 | none |
| **Log R** | **none** | 8.24.04 | 0.78 | 16.79 | 15 | none | 3 | 151 | none |
| **Transform 1/R** | **Arcsine sqrt (POAR)** | 9.21.04 | 0.78 | 0.14 | 15 | none | 3 | 56 | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.77 | 17.36 | 15 | none | 3 | 4 | none |
| **Untransformed (350-1075nm)** | **4th root POAR** | 8.24.04 | 0.73 | 0.39 | 14 | Plot 6 | 4 | 35 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **Square root POAR** | 8.24.04 | 0.73 | 1.60 | 15 | none | 2 | 13 | none |
| **Log R** | **Square root POAR** | 8.24.04 | 0.73 | 1.59 | 15 | none | 3 | 128 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.71 | 12.03 | 15 | none | 1 | 21 | none |
| **Golay 2nd Derivative, avg 10** | **Log POAR** | 8.24.04 | 0.69 | 0.29 | 15 | none | 1 | 67 | none |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.67 | 11.33 | 12 | Plots 1,2,3 | 5 | 522 | Plots 1,2,3: missing reflectance data |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.67 | 20.30 | 15 | none | 2 | 125 | none |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.66 | 22.12 | 15 | none | 4 | 298 | none |
| **Transform 1/R** | **none** | 9.21.04 | 0.66 | 12.79 | 15 | none | 3 | 27 | none |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.66 | 12.64 | 15 | none | 1 | 34 | none |

| Spectra Transformations | *P. arifolium* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Transform 1/R** | **none** | 8.24.04 | 0.64 | 21.00 | 15 | none | 3 | 88 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.64 | 21.73 | 15 | none | 1 | 233 | none |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.63 | 1.92 | 14 | Plot 3 | 4 | 175 | Plot 3: high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.62 | 22.45 | 15 | none | 1 | 233 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.58 | 18.85 | 14 | Plot 3 | 2 | 231 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.55 | 6.17 | 13 | Plots 11, 13 | 3 | 23 | Plots 11, 13: high *P. arifolium* concentrations |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.55 | 23.94 | 15 | none | 1 | 282 | none |
| **Log R** | **Square root POAR** | 9.21.04 | 0.55 | 1.69 | 15 | none | 3 | 8 | none |
| **Untransformed (350-1075nm)** | **Log (base 10) POAR** | 8.24.04 | 0.54 | 0.35 | 14 | Plot 6 | 2 | 257 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.52 | 14.48 | 14 | Plot 3 | 1 | 322 | Plot 3: high *P. arifolium* concentration |
| **MSC Transformation** | **none** | 8.24.04 | 0.39 | 23.80 | 14 | Plot 4 | 1 | 20 | Plot 4: low *P. arifolium* concentration |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.29 | 1.19 | 13 | Plots 8,11 | 1 | 334 | Plots 3,11: high *P. arifolium* concentrations |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.23 | 15.27 | 14 | Plot 3 | 2 | 566 | Plot 3: high *P. arifolium* concentration |

**Table C6. PLS-regressions for *P. arifolium* cover (%) at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *P. arifolium* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.89 | 7.66 | 13 | Plots 1,7 | 3 | 169 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.87 | 8.55 | 14 | Plot 7 | 2 | 11 | Plot 7: low *P. arifolium* concentration |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.77 | 10.99 | 13 | Plots 1,7 | 2 | 16 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.77 | 4.08 | 14 | Plot 11 | 1 | 86 | Plot 11: no *P. arifolium* |
| **Log R** | **none** | 8.24.04 | 0.75 | 11.39 | 13 | Plots 1,7 | 4 | 54 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.74 | 4.60 | 13 | Plots 11,13 | 1 | 85 | Plots 11: no *P. arifolium*; Plot 13: low reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (POAR)** | 8.24.04 | 0.73 | 0.15 | 13 | Plots 1,7 | 3 | 230 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Log R** | **Square root POAR** | 8.24.04 | 0.73 | 0.72 | 13 | Plots 1,7 | 4 | 39 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Golay 2nd Derivative, avg 10** | **Log POAR** | 8.24.04 | 0.73 | 0.07 | 14 | Plot 7 | 1 | 46 | Plot 7: low *P. arifolium* concentration |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.73 | 11.95 | 13 | Plots 1,7 | 3 | 314 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.72 | 11.95 | 13 | Plots 1,7 | 3 | 47 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Norris 1st Derivative** | **none** | 9.21.04 | 0.71 | 6.24 | 15 | none | 1 | 25 | none |
| **Transform 1/R** | **none** | 8.24.04 | 0.70 | 12.22 | 13 | Plots 1,7 | 3 | 374 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.67 | 12.87 | 13 | Plots 1,7 | 1 | 282 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.66 | 13.19 | 13 | Plots 1,7 | 6 | 7 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.66 | 12.93 | 13 | Plots 1,7 | 1 | 244 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.66 | 5.58 | 14 | Plot 11 | 4 | 11 | Plot 11: no *P. arifolium* |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.65 | 23.87 | 14 | Plot 8 | 5 | 353 | Plot 8: high reflectance |
| **Untransformed (350-1075nm)** | **Square root POAR** | 8.24.04 | 0.65 | 0.82 | 13 | Plots 1,7 | 6 | 8 | Plot 1: high reflect.; Plot 7: low *P. arifolium* conc. |

**Table C7. PLS-regression transformations tested on *P. arifolium*.cover (%). Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent)**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (POAR) | 4th root POAR | Sqrt (POAR) | $Log_{10}$ POAR | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (POAR) | Log R | Log R, Sqrt (POAR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | PD site and PA site | | | | | | | | | | |
| 6/3/2004 | PD, PA | | | | | | | | | | |
| 6/16/2004 | PD, PA | | | | | | | | | | |
| 6/29/2004 | PD, PA | | | | | | | | | | |
| 7/19/2004 | PD, PA | | | | | | | | | | |
| 8/24/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | | PD, PA | PD, PA |
| 9/21/2004 | PD, PA | PD, PA | | | | | | PD, PA | PD, PA | | PD, PA |
| 6/6/2005 | PD, PA | | | | | | | | | | |
| 8/2/2005 | PD, PA | | | | | | | | | | |

| | Norris 1st Derivative | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Deriv, Log (POAR) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | |
| 6/3/2004 | | | | | | | |
| 6/16/2004 | | | | | | | |
| 6/29/2004 | | | | | | | |
| 7/19/2004 | | | | | | | |
| 8/24/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA |
| 9/21/2004 | PD, PA | PD, PA | PD, PA | | | | |
| 6/6/2005 | | | | | | | |
| 8/2/2005 | | | | | | | |

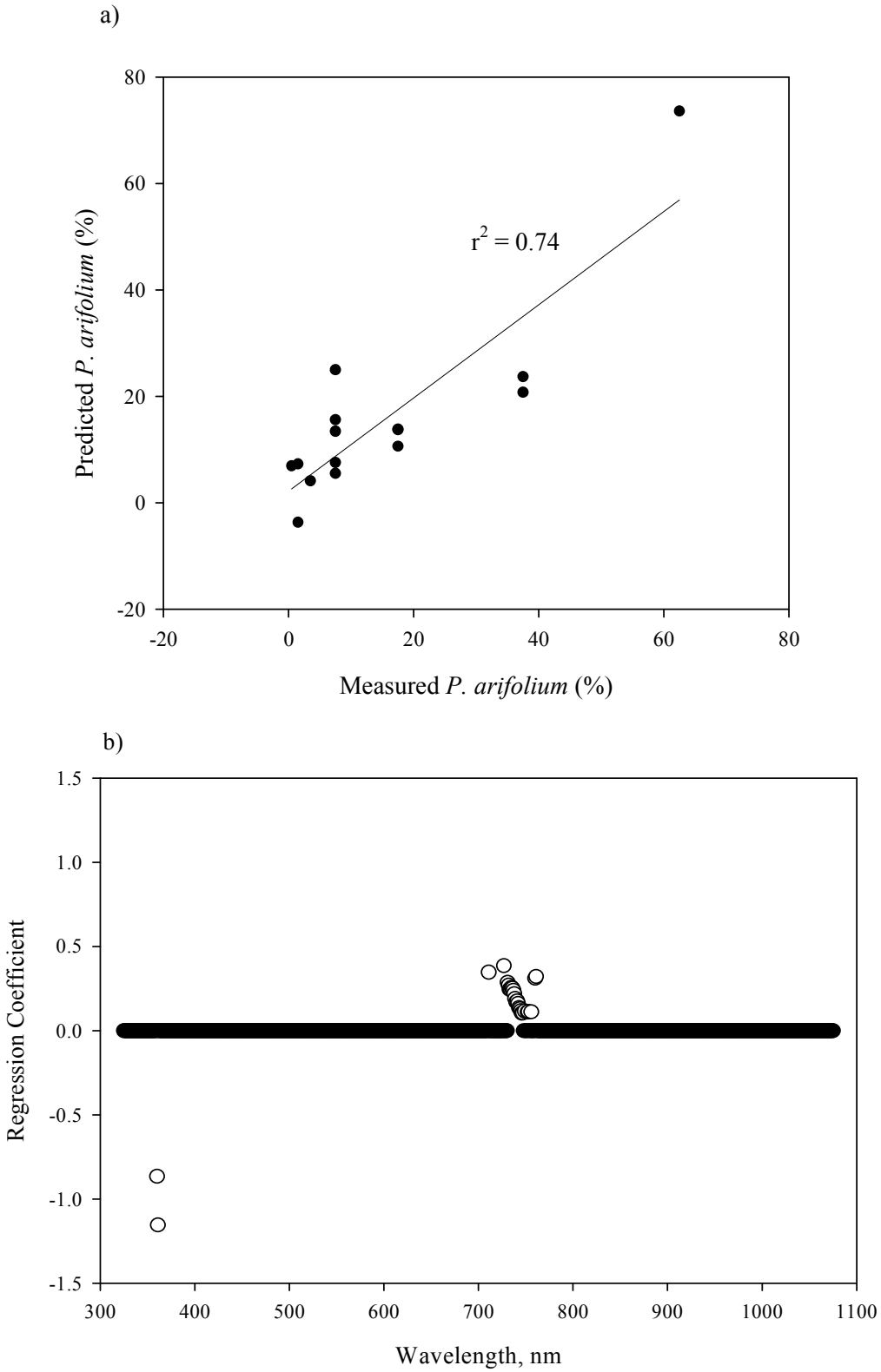



**Figure C7 (a) Predicted vs measured *P. arifolium* cover at the *Phragmites*-dominant site, 9/21/04, using 27 untransformed spectral bands to form three PLS-components with an RMSEP of 8.9% and r = 0.86. (b) Loading plot of regression coefficients for the PLS-regression where spectral bands used in the regression are depicted by open circles.**

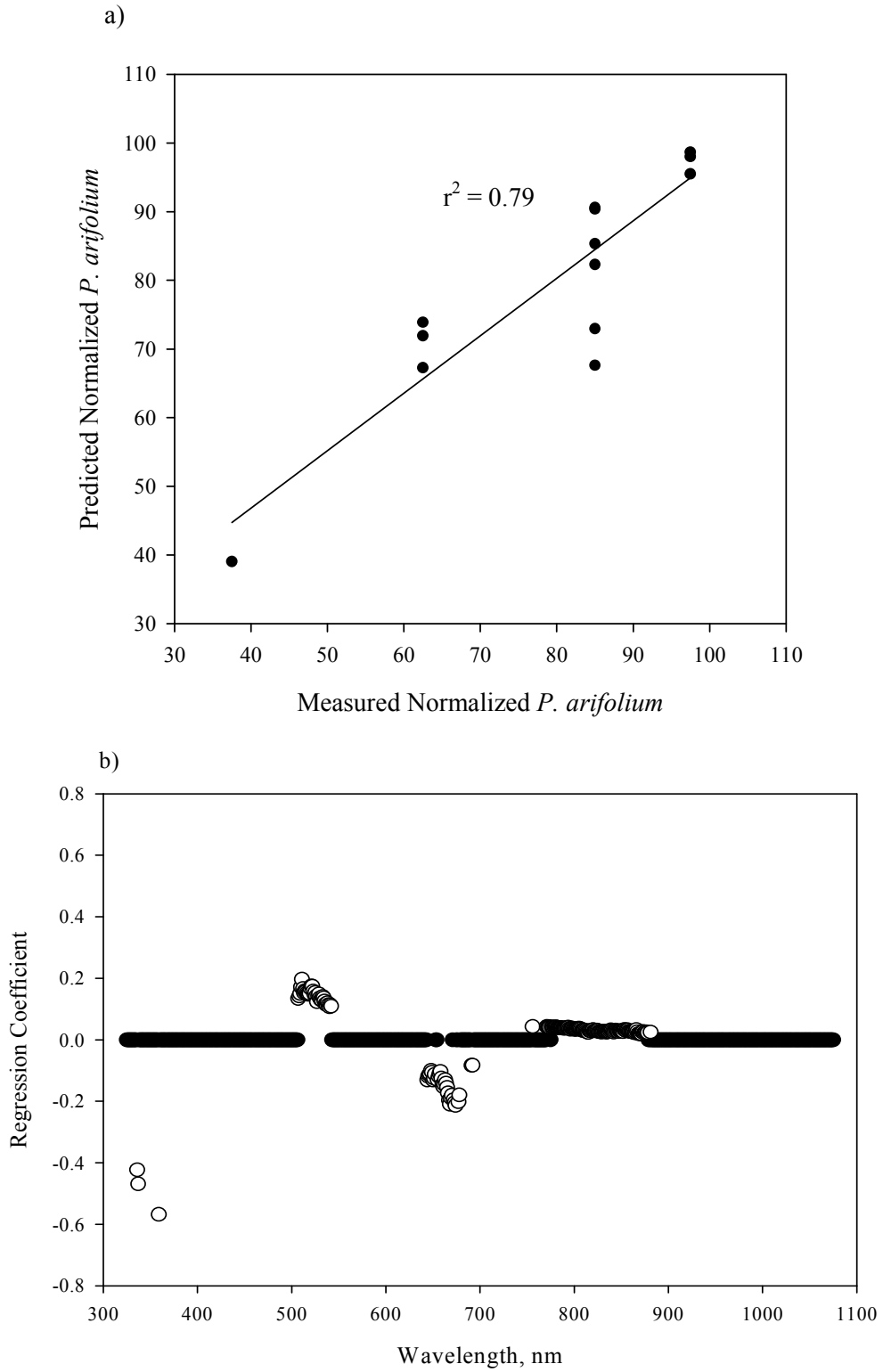



**Figure C8 (a) Predicted vs measured *P. arifolium* cover using 169 spectral bands of normalized spectra at the *Phragmites*-absent site on 8/24/04 to create three PLS-components with RMSEP of 7.7% and r = 0.89. (b) Loading plot of regression coefficients for the PLS-regression where spectral bands used in the regression are depicted by open circles.**

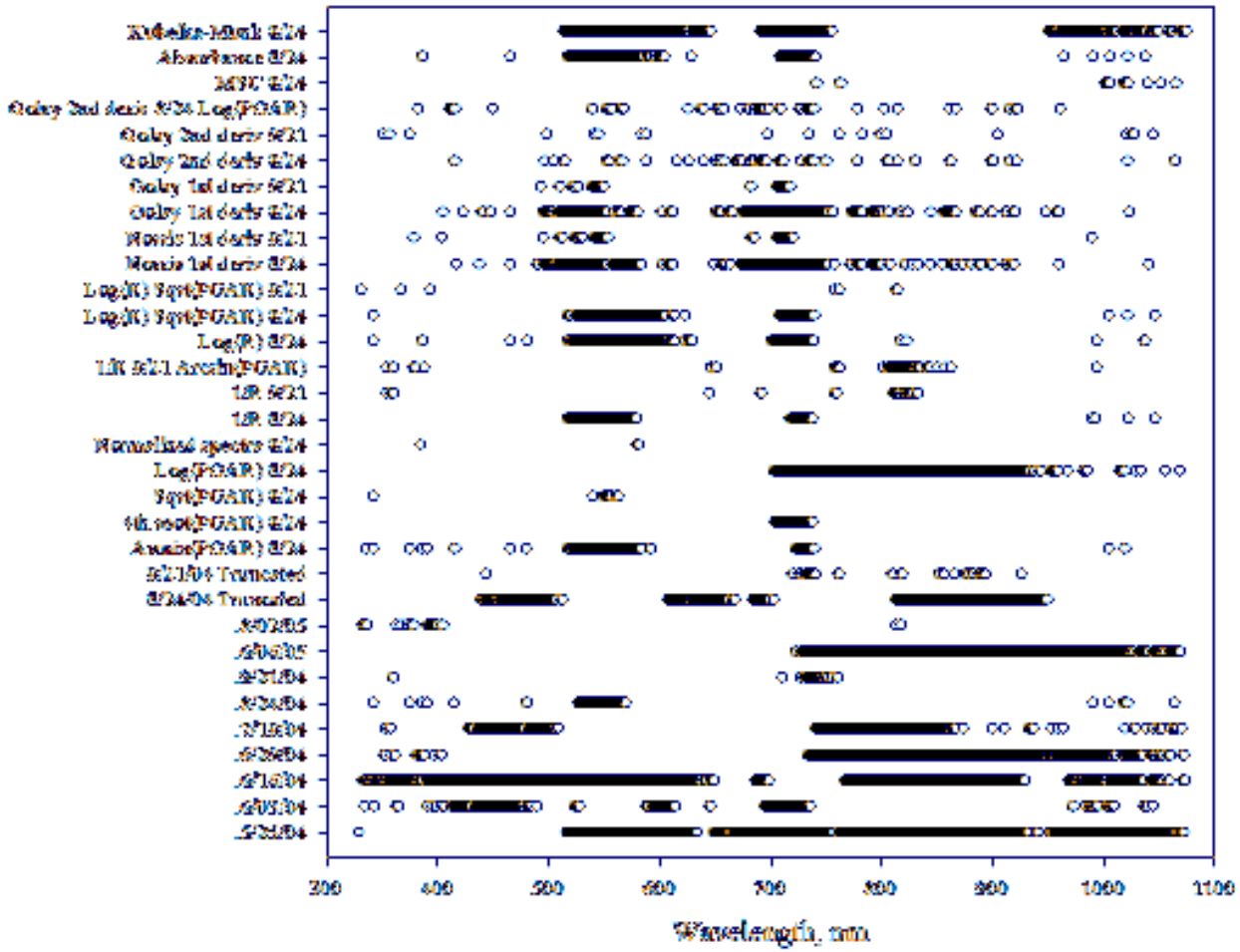



**Figure C9. Significant spectral bands for *P. arifolium* according to PLS-regressions at the *Phragmites*-dominant site.**

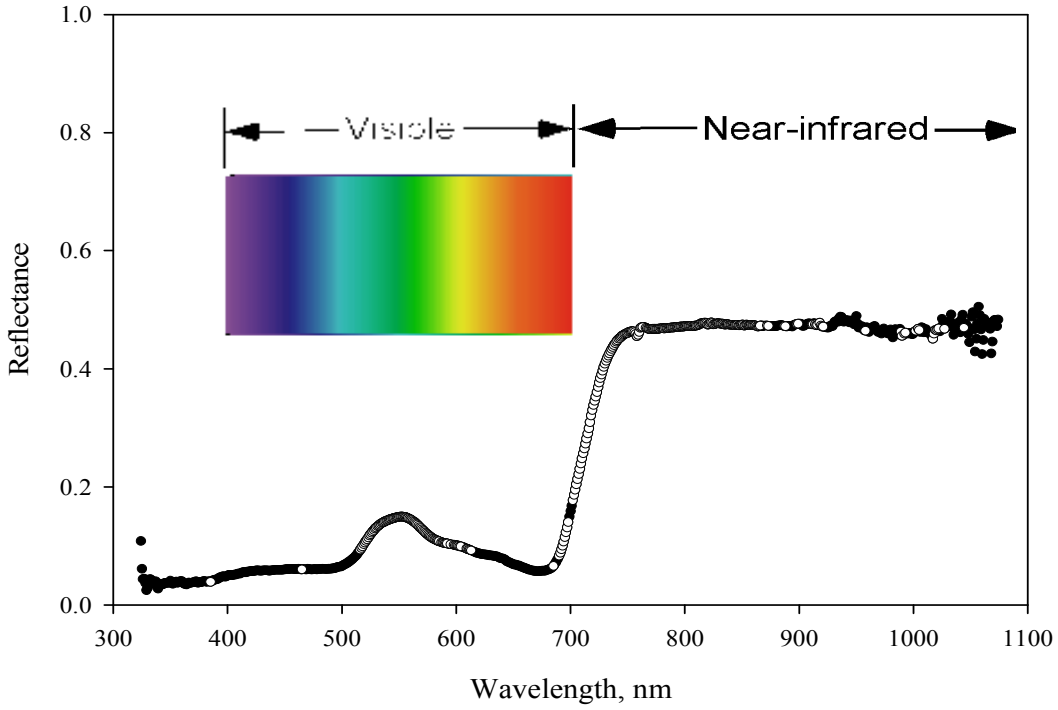



**Figure C10. Spectral bands significant for seven or more regressions for *P. arifolium* at the *Phragmites*-dominant site are indicated by an open circle.**

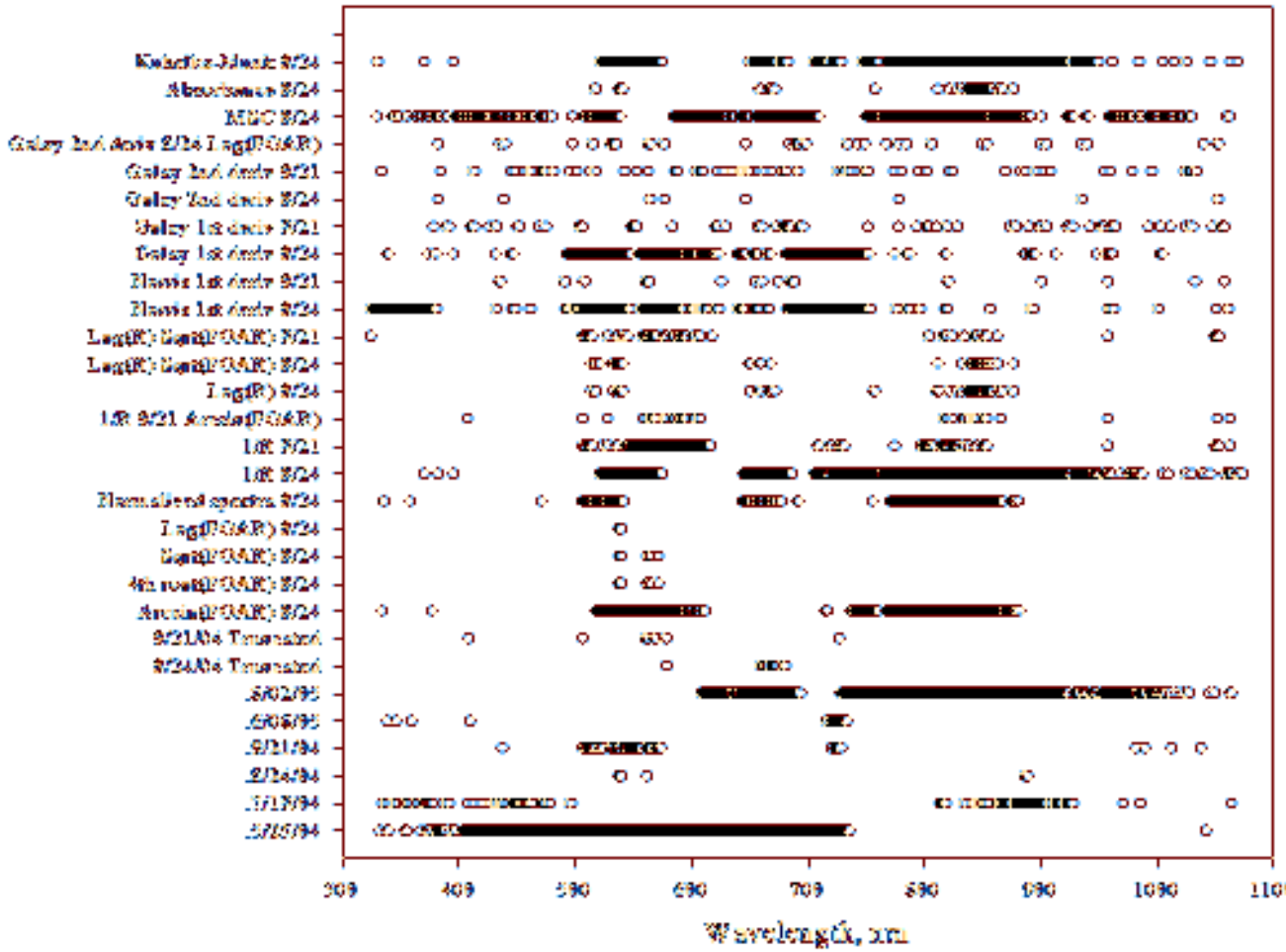



**Figure C11. Significant spectral bands for *P. arifolium* according to PLS-regressions at the *Phragmites*-absent site.**

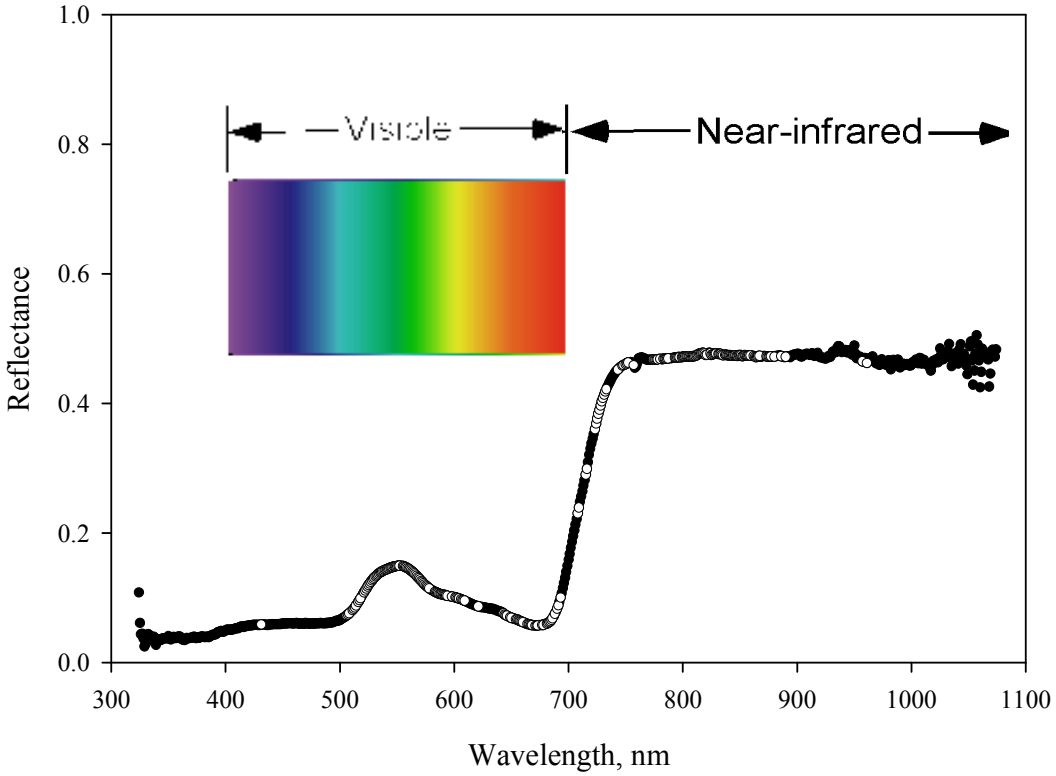



**Figure C12. Spectral bands significant for seven or more regressions for *P. arifolium* at the *Phragmites*-absent site are indicated by an open circle.**

**Table C8. PLS-regressions for *P. virginica* cover (%) at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *Peltandra virginica* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Truncated spectra (400-950nm)** | **none** | 5.25.04 | 0.91 | 7.57 | 11 | Plots 1-3, 12 | 3 | 27 | Plots 1-3: missing refl.; Plot 12: low refl |
| **Truncated spectra (400-950nm)** | **none** | 6.03.04 | 0.87 | 8.61 | 14 | Plot 3 | 8 | 24 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.80 | 11.05 | 10 | Plots 1-3, 9,12 | 2 | 102 | Plots 1-3: missing refl.; Plot 9: hi refl; Plot 12: low refl |
| **Golay 1st Derivative** | **none** | 5.25.04 | 0.79 | 11.06 | 12 | Plots 1-3 | 1 | 69 | Plots 1-3: missing reflectance |
| **Untransformed (350-1075nm)** | **Square root PEVI** | 6.03.04 | 0.78 | 1.39 | 14 | Plot 3 | 3 | 65 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.75 | 11.57 | 14 | Plot 3 | 3 | 33 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (PEVI)** | 6.03.04 | 0.60 | 0.21 | 14 | Plot 3 | 6 | 34 | Plot 3: high reflectance |
| **Log R** | **Square root PEVI** | 6.03.04 | 0.55 | 0.73 | 14 | Plot 3 | 9 | 353 | Plot 3: high reflectance |
| **Norris 1st Derivative** | **none** | 6.03.04 | 0.52 | 16.37 | 15 | none | 1 | 93 | none |
| **Transform 1/R** | **none** | 5.25.04 | 0.50 | 17.34 | 11 | Plots 1-3, 12 | 3 | 39 | Plots 1-3: missing refl; Plot 12: low refl |
| **Transform 1/R** | **none** | 6.03.04 | 0.49 | 17.35 | 14 | Plot 3 | 2 | 55 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.48 | 10.03 | 15 | none | 3 | 56 | none |
| **Kubelka-Munk Transformation** | **none** | 6.03.04 | 0.46 | 16.88 | 14 | Plot 3 | 3 | none | Plot 3: high reflectance |
| **Log R** | **none** | 6.03.04 | 0.45 | 16.57 | 15 | none | 3 | 17 | none |
| **Absorbance Transformation** | **none** | 6.03.04 | 0.41 | 16.24 | 14 | Plot 3 | 3 | 60 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | **4th root PEVI** | 6.03.04 | 0.37 | 0.71 | 15 | none | 1 | 41 | none |
| **Transform 1/R** | **Arcsine sqrt (PEVI)** | 6.03.04 | 0.37 | 0.25 | 14 | Plot 3 | 2 | 323 | Plot 3: high reflectance |

| Spectra Transformations | *Peltandra virginica* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **none** | 5.25.04 | 0.35 | 18.12 | 12 | Plots 1-3 | 1 | 47 | Plots 1-3: missing reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.32 | 12.67 | 13 | Plots 7, 9 | 1 | 357 | Plot 7: low reflectance; Plot 9: high reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 5.25.04 | 0.23 | 18.38 | 12 | Plots 1-3 | 1 | 89 | Plots 1-3: missing reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.17 | 6.53 | 14 | Plot 8 | 2 | 6 | Plot 8: no *P. virginica* concentration |
| **Golay 1st Derivative** | **none** | 6.03.04 | 0.13 | 17.33 | 15 | none | 1 | 124 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 6.03.04 | 0.13 | 17.33 | 15 | none | 1 | 124 | none |
| **MSC Transformation** | **none** | 6.03.04 | 0.13 | 17.33 | 15 | none | 1 | 124 | none |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.01 | 2.96 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.11 | 6.45 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | -0.31 | 11.15 | 15 | none | 1 | none | none |
| **Log R** | **Square root PEVI** | 6.16.04 | -0.38 | 1.24 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | -0.42 | 2.93 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | -0.50 | 5.70 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **Log (base 10) PEVI** | 6.03.04 | -0.72 | 0.89 | 13 | Plots 3,4 | 1 | none | Plots 3,4: no *P. virginica* concentration |

**Table C9. PLS-regressions for *P. virginica* cover (%) at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *Peltandra virginica* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **Square root PEVI** | 9.21.04 | 0.93 | 0.51 | 15 | none | 4 | 243 | none |
| **Transform 1/R** | **none** | 9.21.04 | 0.90 | 2.94 | 15 | none | 5 | 294 | none |
| **Norris 1st Derivative** | **none** | 9.21.04 | 0.86 | 3.28 | 15 | none | 1 | 139 | none |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.84 | 3.65 | 15 | none | 3 | 294 | none |
| **Golay 1st Derivative** | **none** | 9.21.04 | 0.83 | 3.54 | 15 | none | 1 | 223 | none |
| **Truncated spectra (400-950nm)** | **none** | 9.21.04 | 0.82 | 3.90 | 15 | none | 2 | 220 | none |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (PEVI)** | 8.24.04 | 0.81 | 0.04 | 15 | none | 2 | 70 | none |
| **Untransformed (350-1075nm)** | **Square root PEVI** | 8.24.04 | 0.81 | 0.43 | 15 | none | 2 | 70 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.81 | 1.17 | 15 | none | 2 | 104 | none |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.80 | 1.15 | 15 | none | 3 | 56 | none |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.80 | 1.18 | 15 | none | 3 | 64 | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.79 | 4.00 | 15 | none | 2 | 564 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 9.21.04 | 0.75 | 4.28 | 14 | Plot 14 | 1 | 17 | Plot 14: low reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.74 | 1.35 | 15 | none | 3 | 164 | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.72 | 1.36 | 15 | none | 2 | 21 | none |
| **Untransformed (350-1075nm)** | **4th root PEVI** | 8.24.04 | 0.70 | 0.29 | 15 | none | 2 | 43 | none |
| **Log R** | **Square root PEVI** | 8.24.04 | 0.70 | 0.51 | 15 | none | 1 | 378 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.69 | 3.24 | 15 | none | 2 | 165 | none |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.68 | 1.44 | 15 | none | 1 | 247 | none |

**Table C10. PLS-regression transformations performed on spectra and *P. virginica*. cover. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (PEVI) | 4th root PEVI | Sqrt (PEVI) | $Log_{10}$ PEVI | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (PEVI) | Log R | Log R, Sqrt (PEVI) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | PD site and PA site | PD | | | | | | PD | | | |
| 6/3/2004 | PD, PA | PD | PD | PD | PD | PD | | PD | PD | PD | PD |
| 6/16/2004 | PD, PA | | | | | | | | | | PD |
| 6/29/2004 | PD, PA | | | | | | | | | | |
| 7/19/2004 | PD, PA | | | | | | PD | | | | |
| 8/24/2004 | PD, PA | PA | PA | PA | PA | PA | PA | PA | PA | PA | PA |
| 9/21/2004 | PD, PA | PA | | | | | | PA | | | PA |
| 6/6/2005 | PD, PA | | | | | | | | | | |
| 8/2/2005 | PD, PA | | | | | | | | | | |

| | Norris 1st Derivative | Golay 1st Derivative | Golay 2nd Derivative | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|
| 5/25/2004 | PD | PD | PD | | | |
| 6/3/2004 | PD | PD | PD | PD | PD | PD |
| 6/16/2004 | | | | | | |
| 6/29/2004 | | | | | | |
| 7/19/2004 | | | | | | |
| 8/24/2004 | PA | PA | PA | PA | PA | PA |
| 9/21/2004 | PA | PA | PA | | | |
| 6/6/2005 | | | | | | |
| 8/2/2005 | | | | | | |

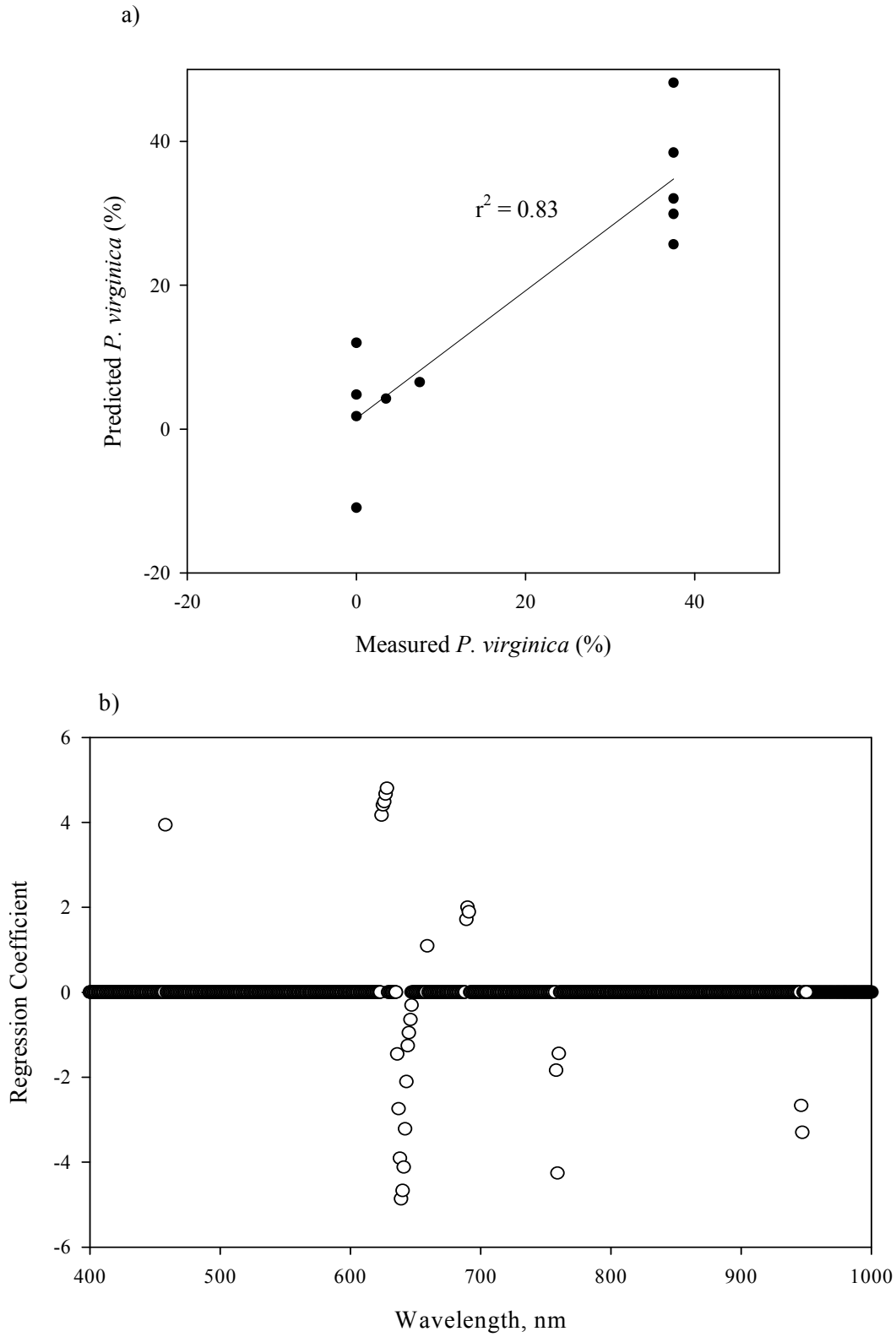



**Figure C13 (a) Predicted vs measured *P. virginica* cover PLS-regression using 27 spectral bands of the truncated spectra at the *Phragmites*-dominant site, 5/25/04 data, that were combined into three PLS-components with an RMSEP of 7.6% and r = 0.91. (b) Loading plot of regression coefficients where spectral bands used in the regression are depicted by open circles.**

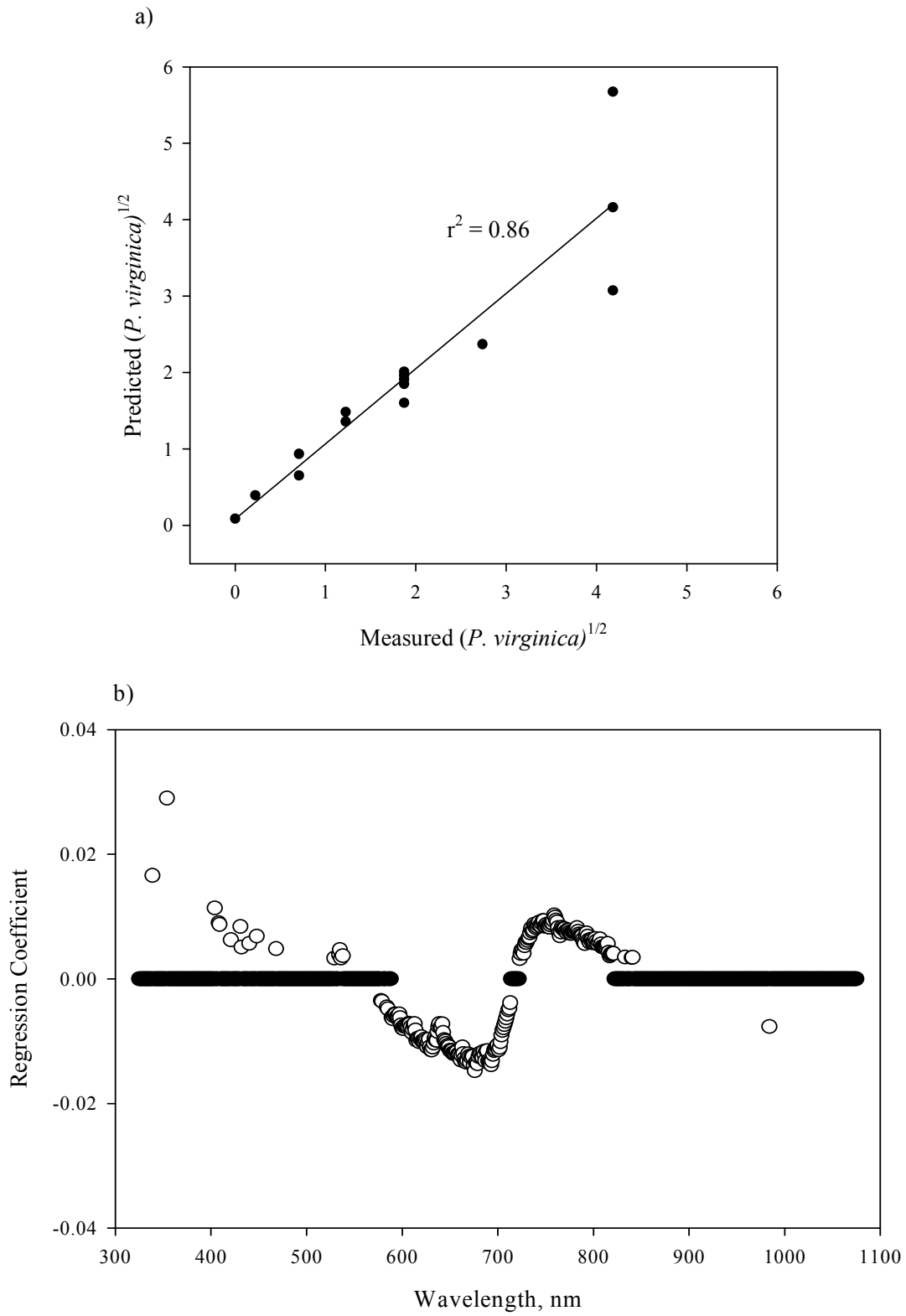



**Figure C14 (a) Predicted vs measured PLS-regression using the square root of *P. virginica* and 243 spectral bands of the log (base 10) of the spectra at the *Phragmites*-absent site, 9/21/04, that were combined into four PLS-components with an RMSEP of 0.51% and r = 0.93. (b) Loading plot of regression coefficients. Spectral bands used in the regression are depicted by open circles.**

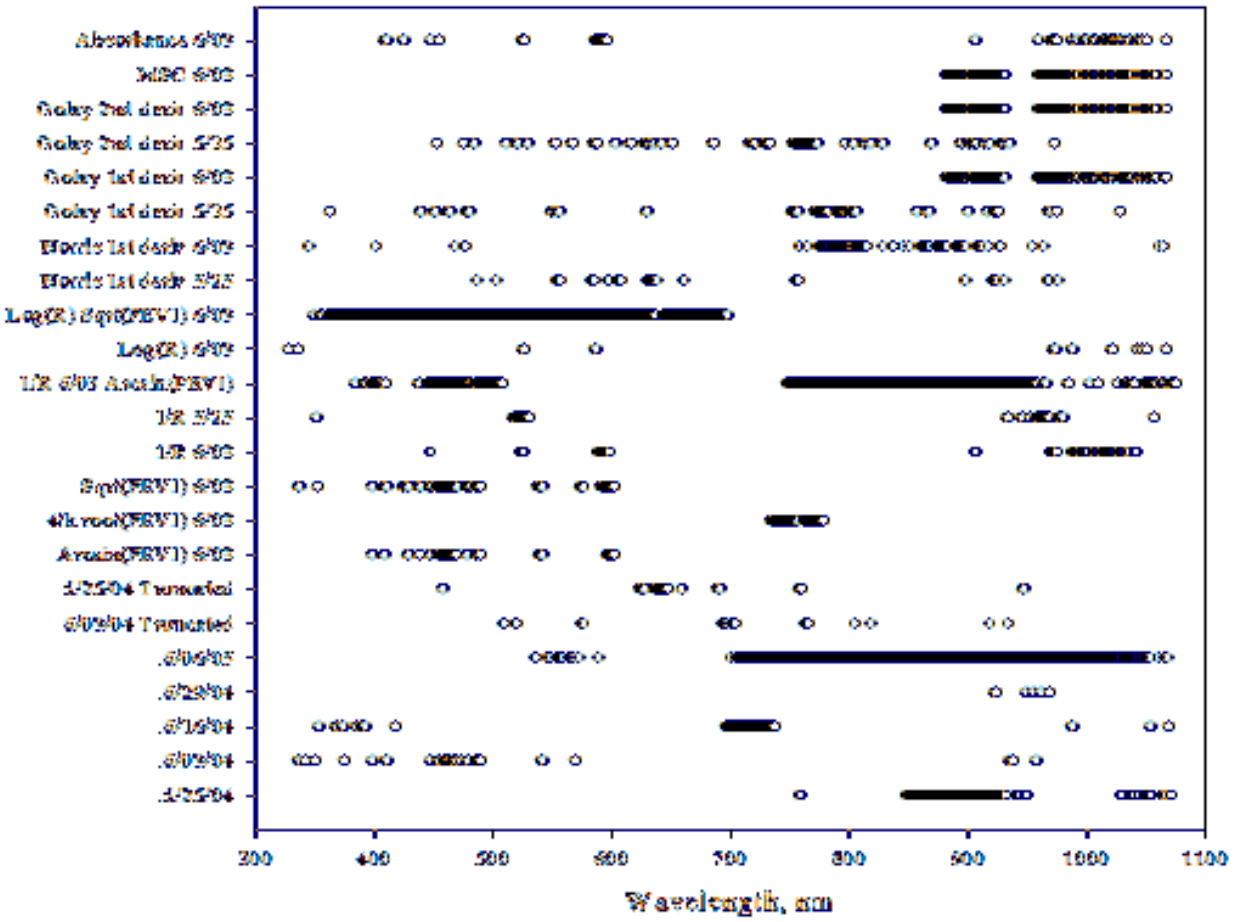



**Figure C15. Significant spectral bands for *P. virginica* according to PLS-regressions at the *Phragmites*-dominant site.**

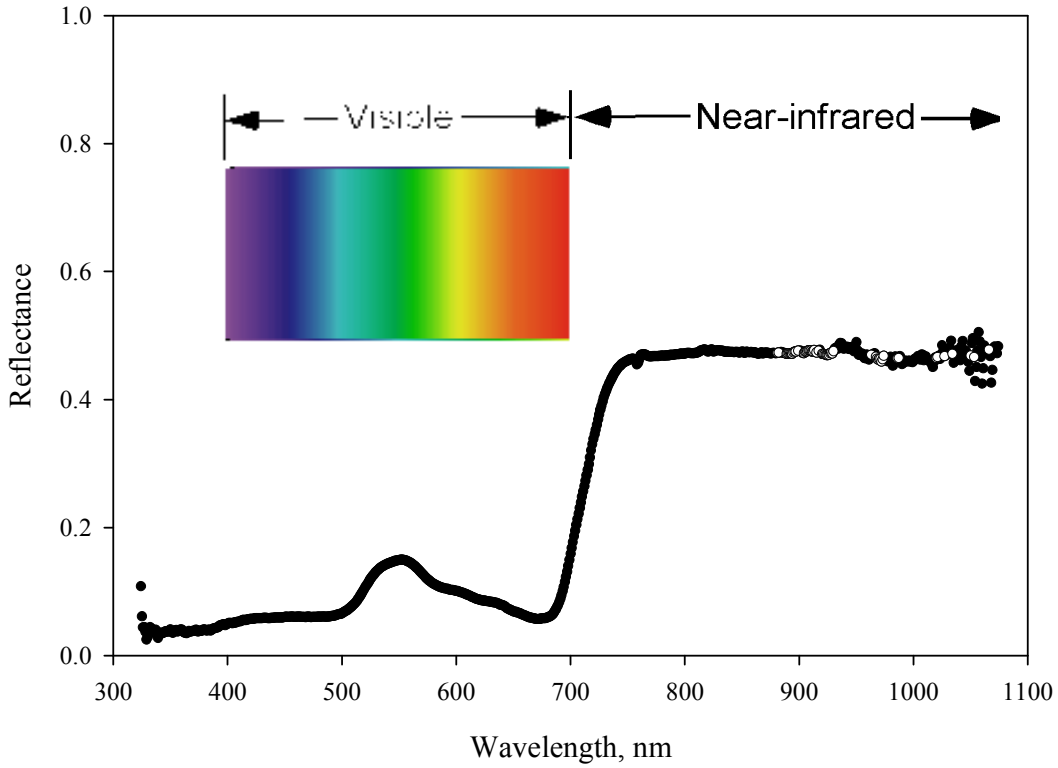



**Figure C16. Spectral bands significant for seven or more regressions for *P. virginica* at the *Phragmites*-dominant site are indicated by an open circle.**

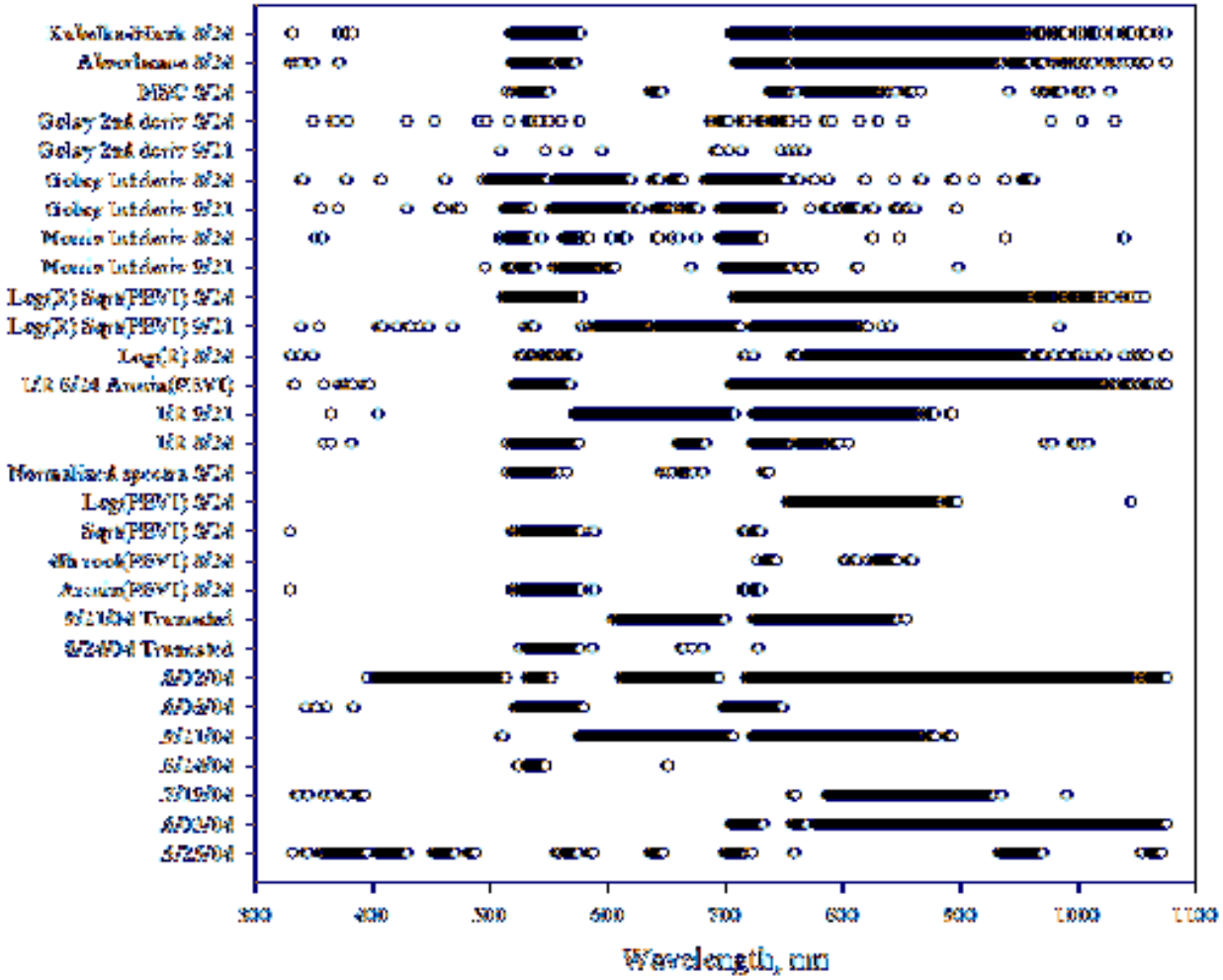



**Figure C17. Significant spectral bands for *P. virginica* according to PLS-regressions at the *Phragmites*-absent site.**

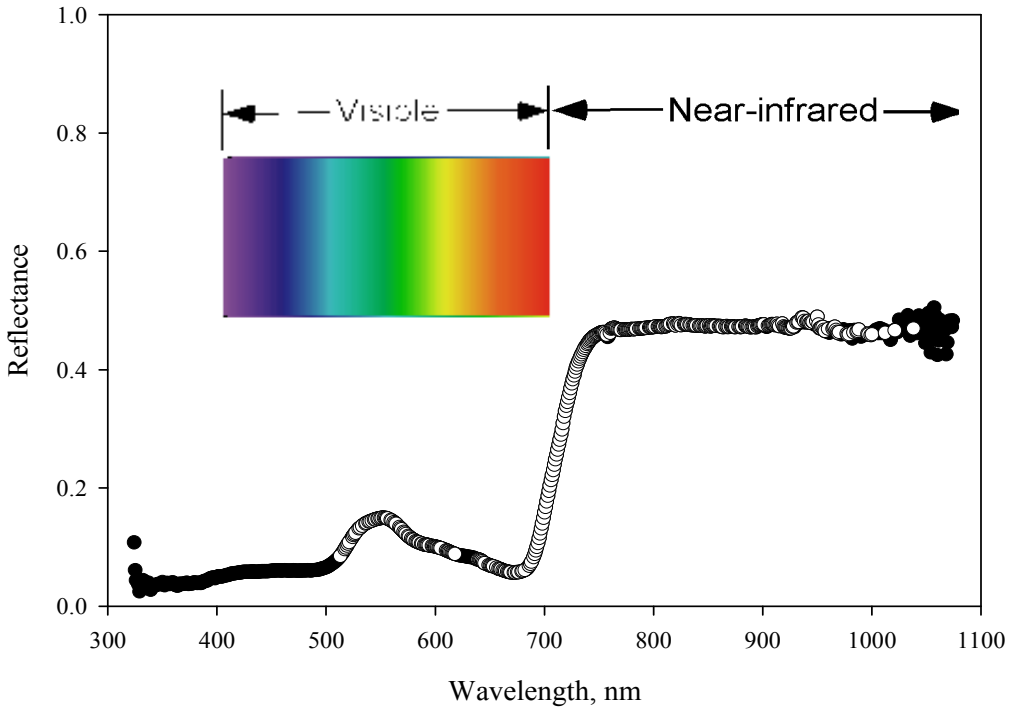



**Figure C18. Spectral bands significant for seven or more regressions for *P. virginica* at the *Phragmites*-absent site are indicated by an open circle.**

**Table C11. PLS-regressions for *Typha* species percent cover at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *Typha* species Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **none** | 8.24.04 | 0.82 | 0.40 | 15 | none | 4 | 13 | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.81 | 0.41 | 15 | none | 5 | 91 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.81 | 0.39 | 15 | none | 1 | 26 | none |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.79 | 0.43 | 13 | Plots 1, 2 | 2 | 47 | Plots 1 and 2: high reflectance |
| **Normalized spectra (R/R410)** | **none** | 8.24.04 | 0.78 | 0.43 | 14 | Plot 1 | 3 | 118 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.76 | 3.39 | 14 | Plot 10 | 2 | 42 | Plot 10: low reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (TYSP)** | 8.24.04 | 0.76 | 0.03 | 15 | none | 2 | 20 | none |
| **Untransformed (350-1075nm)** | **Log (base 10) TYSP** | 8.24.04 | 0.76 | 0.32 | 15 | none | 2 | 8 | none |
| **Untransformed (350-1075nm)** | **Square root TYSP** | 8.24.04 | 0.75 | 0.35 | 15 | none | 2 | 19 | none |
| **Golay 2nd Derivative, avg 10** | **Log TYSP** | 8.24.04 | 0.74 | 0.33 | 15 | none | 1 | 18 | none |
| **Kubelka-Munk Transformation** | **none** | 8.24.04 | 0.73 | 0.46 | 15 | none | 2 | 37 | none |
| **Absorbance Transformation** | **none** | 8.24.04 | 0.72 | 0.48 | 14 | Plot 1 | 3 | 245 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.71 | 0.60 | 15 | none | 4 | 50 | none |
| **Transform 1/R** | **Arcsine sqrt (TYSP)** | 8.24.04 | 0.71 | 0.04 | 14 | Plot 1 | 2 | 126 | Plot 1: high reflectance |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.70 | 0.48 | 14 | Plot 1 | 2 | 148 | Plot 1: high reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.69 | 0.49 | 14 | Plot 1 | 2 | 226 | Plot 1: high reflectance |
| **Transform 1/R** | **none** | 7.19.04 | 0.68 | 0.60 | 15 | none | 3 | 20 | none |

| Spectra Transformations | *Typha* species Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Log R** | **Square root TYSP** | 8.24.04 | 0.68 | 0.39 | 15 | none | 4 | 56 | none |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.68 | 1.48 | 15 | none | 7 | 214 | none |
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.67 | 0.58 | 15 | none | 1 | 9 | none |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.65 | 0.60 | 15 | none | 3 | 66 | none |
| **Untransformed (350-1075nm)** | **4th root TYSP** | 8.24.04 | 0.65 | 0.34 | 14 | Plot 1 | 3 | 330 | Plot 1: high reflectance |
| **Log R** | **Square root TYSP** | 7.19.04 | 0.63 | 0.37 | 15 | none | 8 | 2 | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.58 | 5.58 | 14 | Plot 1 | 9 | 244 | Plot 1: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.47 | 1.94 | 14 | Plot 6 | 1 | 498 | Plot 6: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.45 | 0.97 | 13 | Plots 2, 5 | 2 | 110 | Plot 2: high *Typha* conc.; Plot 5: missing reflect. |
| **MSC Transformation** | **none** | 8.24.04 | 0.44 | 0.62 | 14 | Plot 1 | 1 | 134 | Plot 1: high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.42 | 0.64 | 13 | Plots 1,2 | 1 | 174 | Plots 1 and 2: high reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.39 | 0.73 | 14 | Plot 11 | 1 | 1 | Plot 11: noisy reflectance derivative |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.30 | 0.74 | 14 | Plot 11 | 1 | none | Plot 11: noisy reflectance derivative |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.17 | 2.16 | 13 | Plots 1,9 | 1 | none | Plot 1: high reflectance; Plot 9: missing reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.05 | 1.61 | 14 | Plot 6 | 1 | none | Plot 6: high *Typha* concentration |

**Table C12. PLS-regression transformations tested on spectra and *Typha* species percent cover at the *Phragmites*-absent site.**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (TYSP) | 4th root TYSP | Sqrt (TYSP) | $Log_{10}$ TYSP | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (TYSP) | Log R | Log R, Sqrt (TYSP) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | X | | | | | | | | | | |
| 6/3/2004 | X | | | | | | | | | | |
| 6/16/2004 | X | | | | | | | | | | |
| 6/29/2004 | X | | | | | | | | | | |
| 7/19/2004 | X | X | | | | | | X | | | X |
| 8/24/2004 | X | X | X | X | X | X | X | X | X | X | X |
| 9/21/2004 | X | | | | | | | | | | |
| 6/6/2005 | X | | | | | | | | | | |
| 8/2/2005 | X | | | | | | | | | | |

| | Norris 1st Derivative | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Derivative, Log (TYSP) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | |
| 6/3/2004 | | | | | | | |
| 6/16/2004 | | | | | | | |
| 6/29/2004 | | | | | | | |
| 7/19/2004 | X | X | X | | | | |
| 8/24/2004 | X | X | X | X | X | X | X |
| 9/21/2004 | | | | | | | |
| 6/6/2005 | | | | | | | |
| 8/2/2005 | | | | | | | |

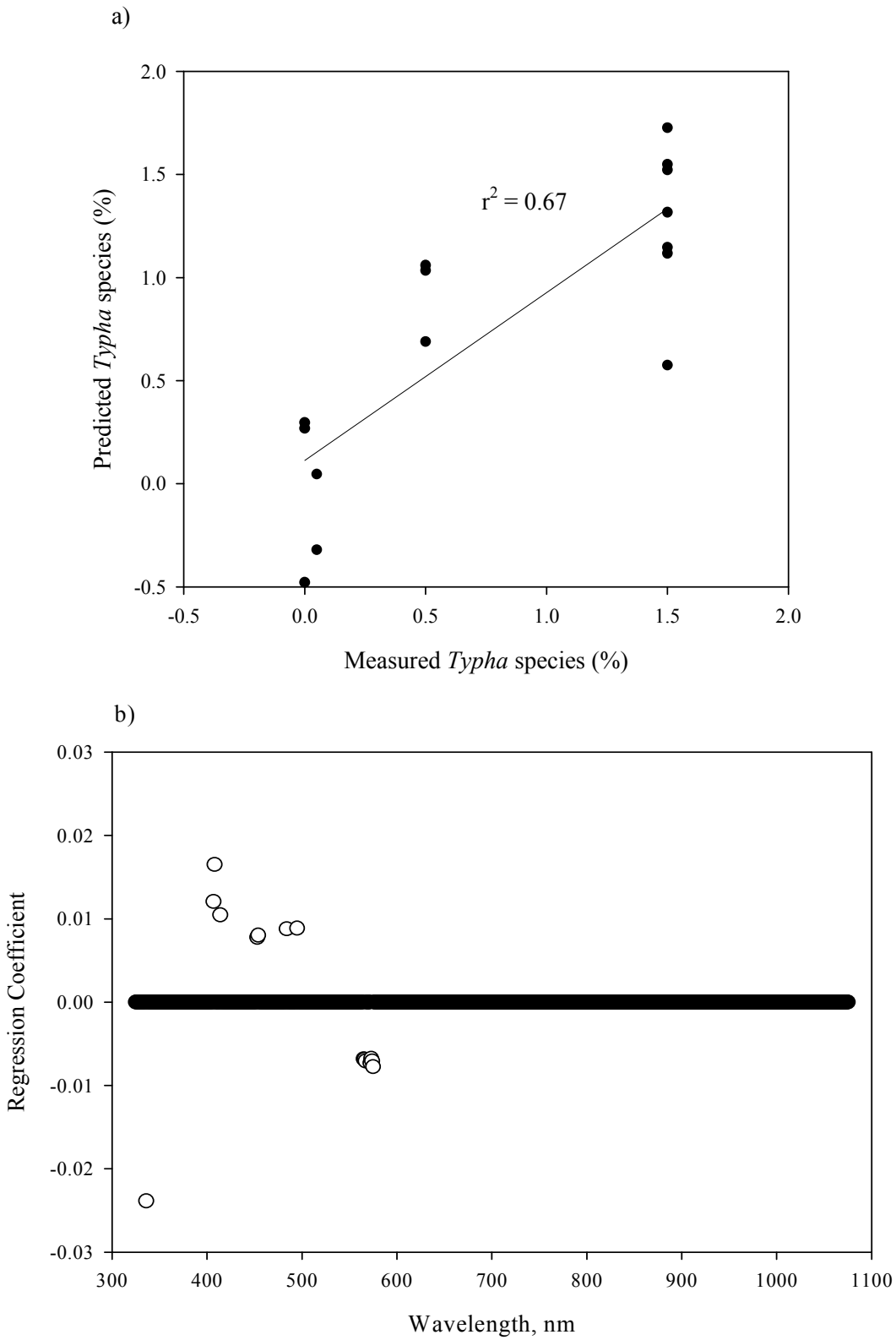



**Figure C19. (a) Predicted vs measured *Typha* species cover PLS-regression using 13 spectral bands of the log of the reflectance at the *Phragmites*-absent site on 8/24/04 to form four PLS-components with an RMSEP of 0.4% and r = 0.82. (b) Loading plot of regression coefficients. Spectral bands used in the regression are depicted by open circles.**

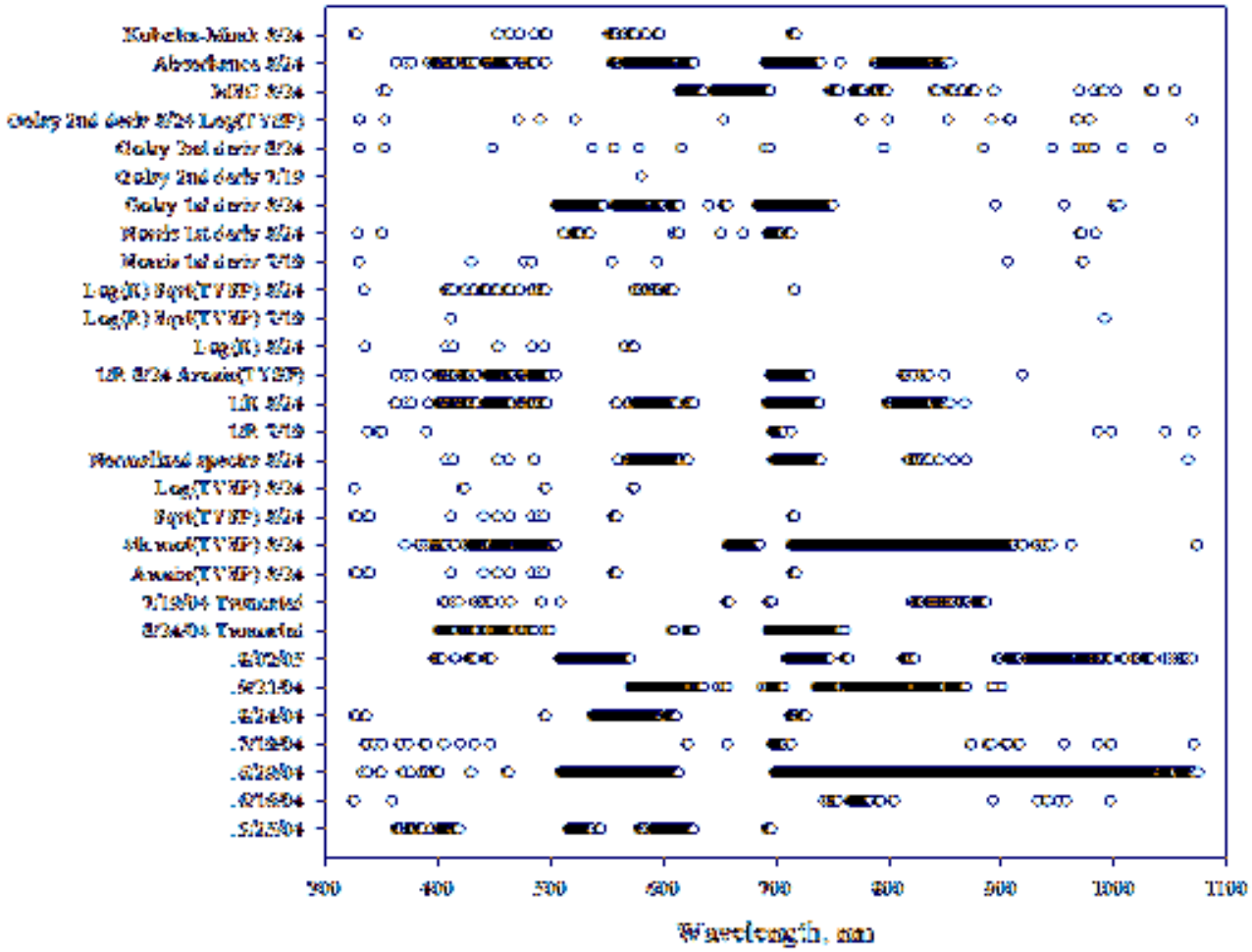



**Figure C20. Significant spectral bands for *Typha* species according to PLS-regressions at the *Phragmites*-absent site.**

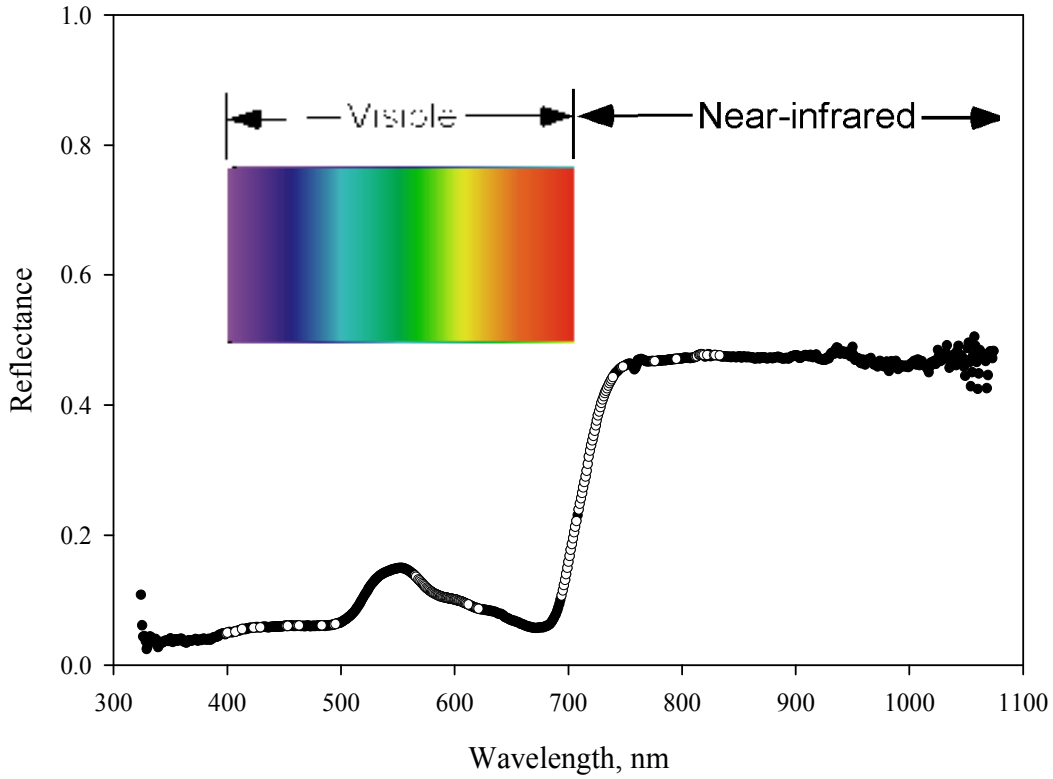



**Figure C21. Spectral bands significant for seven or more regressions for *Typha* species at the *Phragmites*-absent site are indicated by an open circle.**

**Table C13. PLS-regressions for *I. capensis* percent cover at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *I. capensis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.90 | 10.74 | 13 | Plot 1, 14 | 4 | 45 | Plot 1: high reflect.; Plot 14: low *I. capensis* conc. |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.90 | 10.85 | 13 | Plots 1,14 | 2 | 60 | Plot 1: high reflect.; Plot 14: low *I. capensis* conc. |
| **Log R** | **Square root IMCA** | 8.24.04 | 0.90 | 0.87 | 14 | Plot 4 | 9 | 44 | Plot 4: low reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (IMCA)** | 7.19.04 | 0.83 | 0.18 | 14 | Plot 1 | 2 | 9 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **Square root IMCA** | 7.19.04 | 0.83 | 1.49 | 14 | Plot 1 | 2 | 11 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **4th root IMCA** | 7.19.04 | 0.82 | 0.39 | 14 | Plot 1 | 3 | 14 | Plot 1: high reflectance |
| **Golay 2nd Derivative, avg 10** | **Log IMCA** | 7.19.04 | 0.79 | 0.34 | 13 | Plots 3,14 | 1 | 60 | Plot 3: high reflect. ; Plot 14: low *I. capensis* conc. |
| **Log R** | **none** | 7.19.04 | 0.77 | 15.82 | 14 | Plot 1 | 3 | 14 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.75 | 17.55 | 14 | Plot 1 | 2 | 6 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (IMCA)** | 8.24.04 | 0.73 | 0.18 | 14 | Plot 6 | 3 | 61 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **Log (base 10) IMCA** | 7.19.04 | 0.72 | 0.38 | 13 | Plot 1, 14 | 3 | 10 | Plot 1: high reflect.; Plot 14: low *I. capensis* conc. |
| **Log R** | **Square root IMCA** | 7.19.04 | 0.72 | 1.79 | 14 | Plot 1 | 2 | 16 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.69 | 21.45 | 14 | Plot 7 | 2 | 50 | Plot 7: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.68 | 15.53 | 14 | Plot 6 | 3 | 148 | Plot 6: high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.67 | 15.13 | 14 | Plot 6 | 1 | 15 | Plot 6: high reflectance |
| **MSC Transformation** | **none** | 7.19.04 | 0.66 | 18.06 | 14 | Plot 14 | 6 | none | Plot 14: low *I. capensis* concentration |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.66 | 15.23 | 14 | Plot 6 | 1 | 9 | Plot 6: high reflectance |

| Spectra Transformations | *I. capensis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.61 | 16.29 | 13 | Plots 4,6 | 1 | 4 | Plot 4: low reflectance; Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.54 | 14.92 | 15 | none | 2 | 448 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.54 | 22.08 | 14 | Plot 3 | 1 | 16 | Plot 3: high amount of noise in reflect. derivative |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.52 | 13.69 | 15 | none | 3 | 50 | none |
| **Transform 1/R** | **Arcsine sqrt (IMCA)** | 7.19.04 | 0.50 | 0.25 | 14 | Plot 14 | 5 | 4 | Plot 14: low *I. capensis* concentration |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.49 | 12.24 | 12 | Plots 1,2,3 | 2 | 50 | Plots 1,2,3: missing reflectance |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.48 | 20.36 | 14 | Plot 14 | 1 | 269 | Plot 14: low *I. capensis* concentration |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.47 | 23.34 | 13 | Plot 1, 14 | 3 | 38 | Plot 1: high reflect.; Plot 14: low *I. capensis* conc. |
| **Kubelka-Munk Transformation** | **none** | 7.19.04 | 0.47 | 21.34 | 14 | Plot 14 | 3 | 13 | Plot 14: low *I. capensis* concentration |
| **Transform 1/R** | **none** | 7.19.04 | 0.44 | 22.24 | 14 | Plot 14 | 3 | 21 | Plot 14: low *I. capensis* concentration |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.37 | 28.25 | 15 | none | 1 | none | none |
| **Absorbance Transformation** | **none** | 7.19.04 | 0.30 | 22.17 | 14 | Plot 14 | 1 | 73 | Plot 14: low *I. capensis* concentration |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.27 | 14.55 | 13 | Plots 10,12 | 1 | 124 | Plots 10,12: high *I. capensis* concentration |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.19 | 10.17 | 13 | Plots 3,13 | 1 | none | Plot 3: high reflectance; Plot 13: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | -0.31 | 27.30 | 15 | none | 1 | none | none |

**Table C14. PLS-regressions for *I. capensis* percent cover at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | *I. capensis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Transform 1/R** | **none** | 7.19.04 | 0.90 | 13.09 | 14 | Plot 15 | 3 | 26 | Plot 15: *I. capensis* missing |
| **Log R** | **none** | 7.19.04 | 0.89 | 15.04 | 14 | Plot 15 | 8 | 59 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.87 | 14.63 | 13 | Plots 11, 14 | 7 | 50 | Plot 11: high reflectance; Plot 14: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.86 | 15.85 | 14 | Plot 15 | 6 | 34 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.85 | 6.92 | 12 | Plots 1, 9, 15 | 8 | 99 | Plot 1: high refl; Plot 9: no reflt; Plot 15: low refl. |
| **Log R** | **Square root IMCA** | 7.19.04 | 0.84 | 1.70 | 14 | Plot 15 | 5 | 42 | Plot 15: *I. capensis* missing |
| **Absorbance Transformation** | **none** | 7.19.04 | 0.84 | 16.65 | 14 | Plot 15 | 3 | 53 | Plot 15: *I. capensis* missing |
| **Transform 1/R** | **Arcsine sqrt (IMCA)** | 7.19.04 | 0.82 | 0.21 | 14 | Plot 15 | 4 | 34 | Plot 15: *I. capensis* missing |
| **MSC Transformation** | **none** | 7.19.04 | 0.81 | 19.64 | 14 | Plot 15 | 2 | 13 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (IMCA)** | 7.19.04 | 0.80 | 0.25 | 14 | Plot 15 | 2 | 10 | Plot 15: *I. capensis* missing |
| **Kubelka-Munk Transformation** | **none** | 7.19.04 | 0.79 | 18.67 | 14 | Plot 15 | 3 | 78 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **Square root IMCA** | 7.19.04 | 0.77 | 2.13 | 14 | Plot 15 | 2 | 6 | Plot 15: *I. capensis* missing |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.77 | 19.64 | 14 | Plot 15 | 2 | 72 | Plot 15: *I. capensis* missing |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.76 | 19.78 | 14 | Plot 15 | 3 | 10 | Plot 15: *I. capensis* missing |
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.74 | 20.21 | 14 | Plot 15 | 1 | 20 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **4th root IMCA** | 7.19.04 | 0.72 | 0.59 | 14 | Plot 15 | 2 | 4 | Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.71 | 19.40 | 13 | Plots 1,15 | 2 | 56 | Plot 1: high reflectance; Plot 15: low reflectance |

| Spectra Transformations | *I. capensis* Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.69 | 18.90 | 15 | none | 1 | 75 | none |
| **Log R** | **Square root IMCA** | 8.24.04 | 0.68 | 2.33 | 13 | Plots 1,15 | 2 | 408 | Plot 1: high reflectance; Plot 15: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.67 | 23.33 | 14 | Plot 6 | 2 | 43 | Plot 6: low reflectance |
| **Norris 1st Derivative** | **none** | 8.24.04 | 0.67 | 19.75 | 15 | none | 2 | 51 | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.66 | 23.33 | 15 | none | 2 | 63 | none |
| **Untransformed (350-1075nm)** | **Log (base 10) IMCA** | 7.19.04 | 0.64 | 0.64 | 14 | Plot 15 | 2 | 4 | Plot 15: *I. capensis* missing |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.61 | 21.30 | 14 | Plot 1 | 1 | 18 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.56 | 19.78 | 14 | Plot 3 | 1 | 385 | Plot 3: high reflectance |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.55 | 29.52 | 14 | Plot 15 | 3 | 11 | Plot 15: *I. capensis* missing |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.55 | 23.27 | 13 | Plots 1,15 | 2 | 298 | Plot 1: high reflectance; Plot 15: low reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.51 | 24.75 | 13 | Plots 1,15 | 2 | none | Plot 1: high reflectance; Plot 15: low reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.46 | 28.19 | 13 | Plots 8, 15 | 1 | 18 | Plot 8: noisy derivative; Plot 15: *I. capensis* missing |
| **Golay 2nd Derivative, avg 10** | **Log IMCA** | 7.19.04 | 0.25 | 0.68 | 13 | Plots 8, 15 | 1 | 5 | Plot 8: noisy derivative; Plot 15: *I. capensis* missing |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.20 | 26.50 | 14 | Plot 12 | 1 | 64 | Plot 12: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | -0.10 | 31.49 | 15 | none | 1 | none | none |

**Table C15. PLS-regression transformations tested on spectra and *I. capensis* percent cover. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (IMCA) | 4th root IMCA | Sqrt (IMCA) | $Log_{10}$ IMCA | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (IMCA) | Log R | Log R, Sqrt (IMCA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | PD site and PA site | | | | | | | | | | |
| 6/3/2004 | PD, PA | | | | | | | | | | |
| 6/16/2004 | PD, PA | | | | | | | | | | |
| 6/29/2004 | PD, PA | | | | | | | | | | |
| 7/19/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA |
| 8/24/2004 | PD, PA | PD, PA | PD | | | | | PA | | | PD, PA |
| 9/21/2004 | PD, PA | | | | | | | | | | |
| 6/6/2005 | PD, PA | | | | | | | | | | |
| 8/2/2005 | PD, PA | | | | | | | | | | |

| | Norris 1st Derivative | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Derivative, Log (IMCA) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | |
| 6/3/2004 | | | | | | | |
| 6/16/2004 | | | | | | | |
| 6/29/2004 | | | | | | | |
| 7/19/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA |
| 8/24/2004 | PD, PA | PD, PA | PD, PA | | | | |
| 9/21/2004 | | | | | | | |
| 6/6/2005 | | | | | | | |
| 8/2/2005 | | | | | | | |

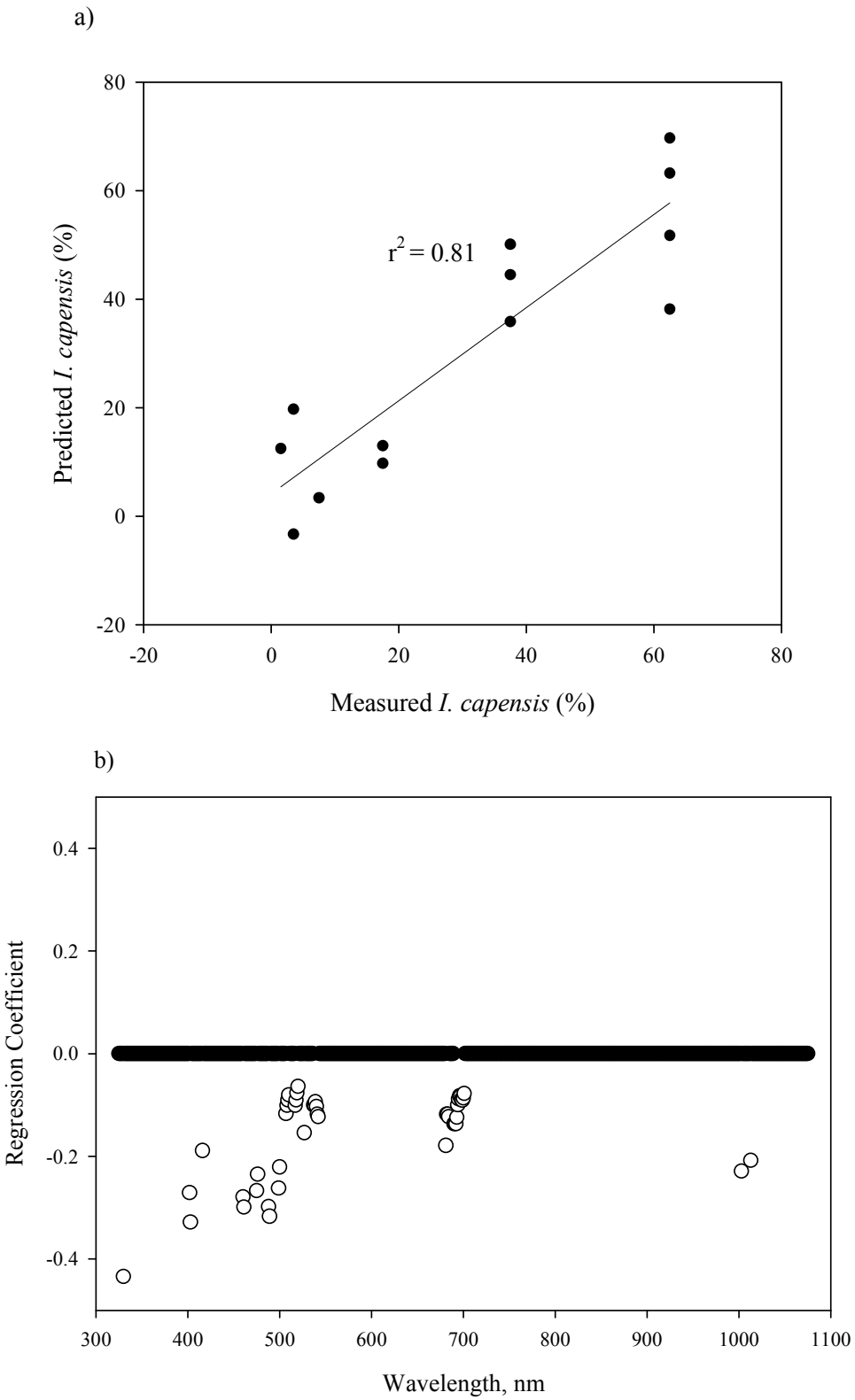



**Figure C22 (a) Predicted vs measured *I. capensis* cover using 45 spectral bands of first derivative transformed reflectance at the *Phragmites*-dominant site on 7/19/04 to combine into four PLS-components with an RMSEP of 10.8% and r = 0.90. (b) Loading plot of regression coefficients where spectral bands used in the regression are depicted by open circles.**

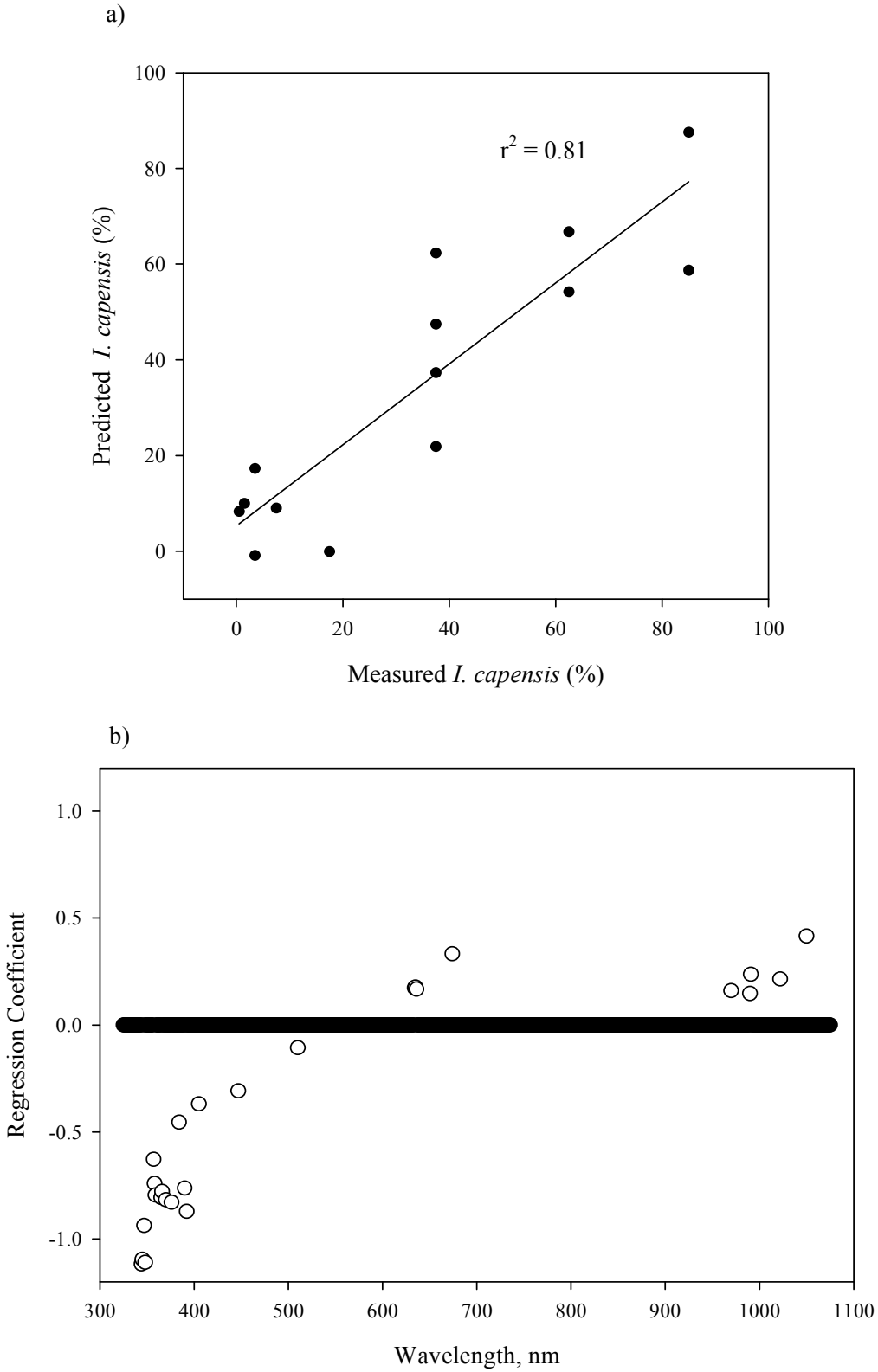



**Figure C23. (a) Predicted vs measured *I. capensis* percent cover PLS-regression using 26 spectral bands of inverse reflectance at the *Phragmites*-absent site on 7/19/04 to combine into three PLS-components with an RMSEP of 13% and r = 0.90. (b) Loading plot of regression coefficients where spectral bands used in the regression are depicted by open circles.**

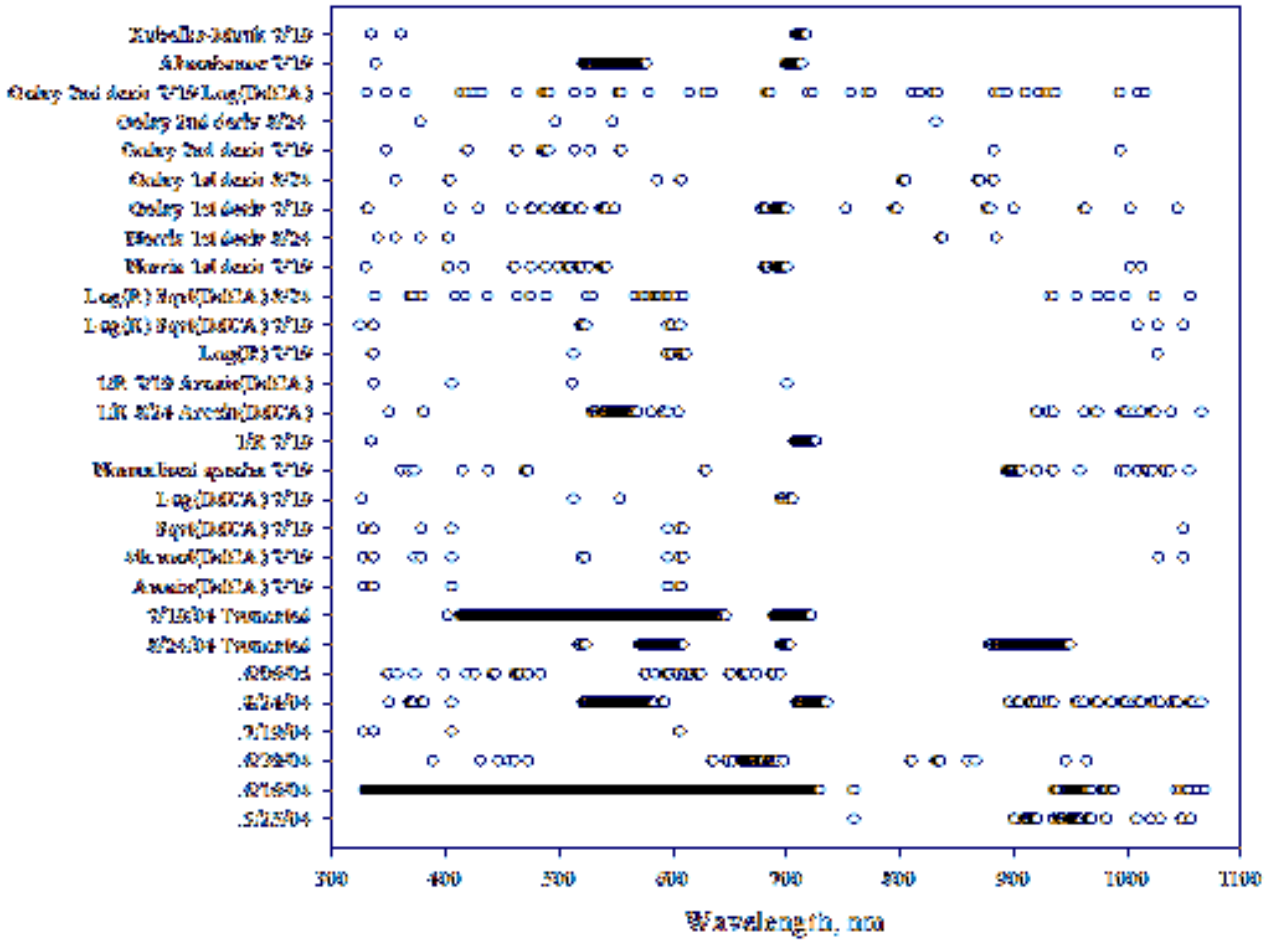



**Figure C24. Significant spectral bands for *I. capensis* according to PLS-regressions at the *Phragmites*-dominant site.**

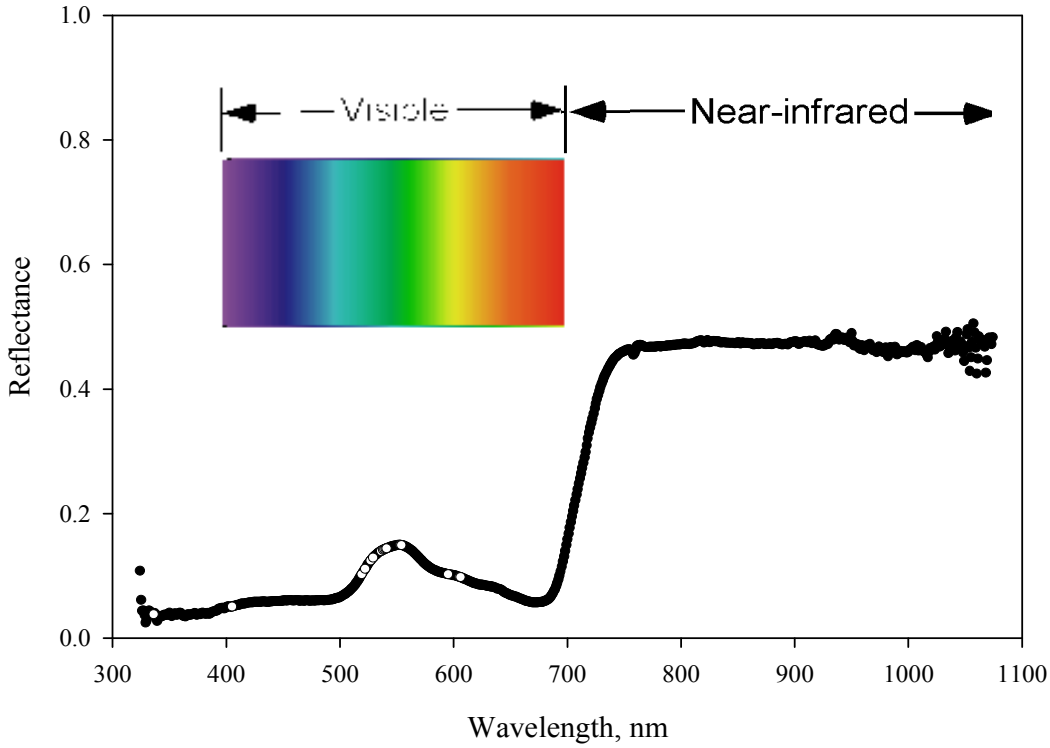



**Figure C25. Spectral bands significant for seven or more regressions for *I. capensis* at the *Phragmites*-dominant site are indicated by an open circle.**

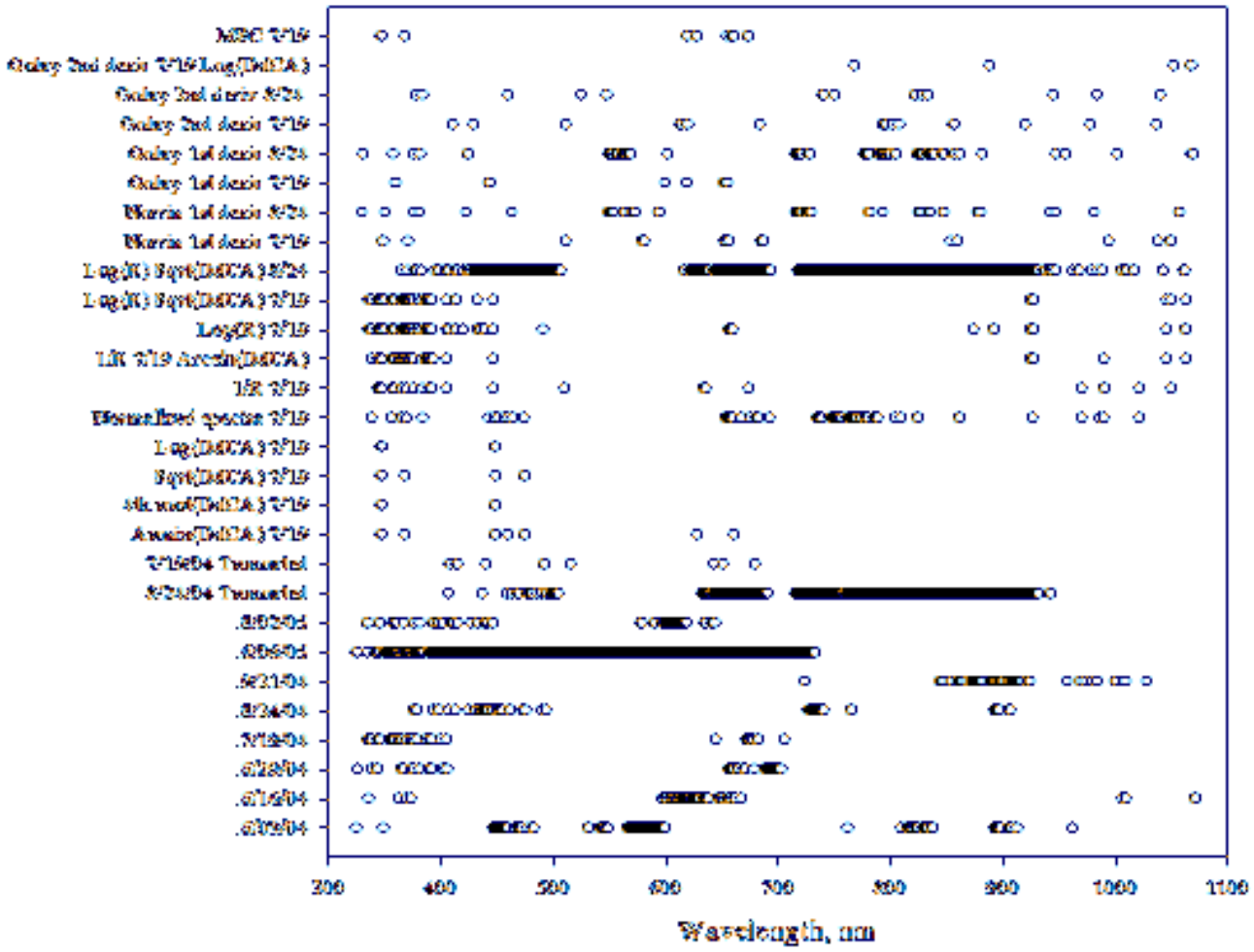



**Figure C26. Significant spectral bands for *I. capensis* according to PLS-regressions at the *Phragmites*-absent site.**

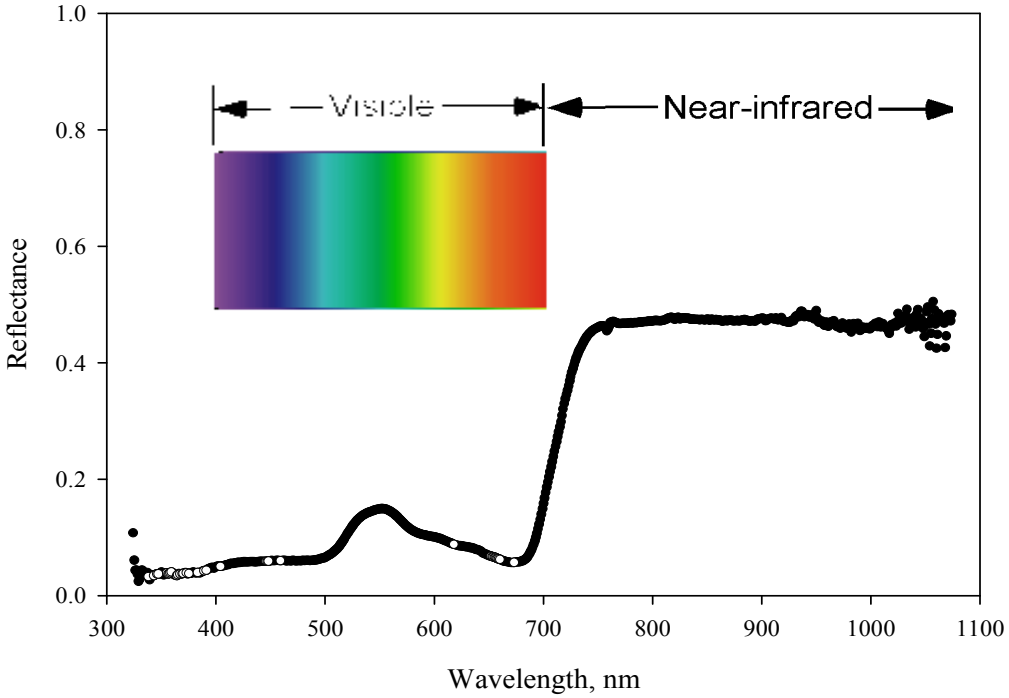



**Figure C27. Spectral bands significant for seven or more regressions for *I. capensis* at the *Phragmites*-absent site are indicated by an open circle.**

**Table C16. PLS-regressions for LAI at the *Phragmites*-dominant (PD) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | LAI Transform-ations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.90 | 0.46 | 15 | none | 10 | 107 | none |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.89 | 0.42 | 14 | Plot 8 | 10 | 31 | Plot 8: high LAI |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (LAI)** | 7.19.04 | 0.89 | 0.01 | 14 | Plot 8 | 10 | 30 | Plot 8: high LAI |
| **Untransformed (350-1075nm)** | **Square root LAI** | 7.19.04 | 0.89 | 0.09 | 14 | Plot 8 | 10 | 30 | Plot 8: high LAI |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.87 | 0.45 | 14 | Plot 8 | 5 | 38 | Plot 8: high LAI |
| **Transform 1/R** | **Arcsine sqrt (LAI)** | 7.19.04 | 0.84 | 0.01 | 14 | Plot 8 | 3 | 97 | Plot 8: high LAI |
| **MSC Transformation** | **none** | 7.19.04 | 0.84 | 0.50 | 14 | Plot 8 | 4 | 34 | Plot 8: high LAI |
| **Untransformed (350-1075nm)** | **4th root LAI** | 7.19.04 | 0.83 | 0.04 | 14 | Plot 8 | 10 | 27 | Plot 8: high LAI |
| **Transform 1/R** | **none** | 7.19.05 | 0.82 | 0.51 | 14 | Plot 8 | 3 | 93 | Plot 8: high LAI |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 9.21.04 | 0.80 | 0.05 | 15 | none | 1 | 17 | none |
| **Log R** | **Square root LAI** | 7.19.04 | 0.76 | 0.13 | 14 | Plot 8 | 3 | 93 | Plot 8: high LAI |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.76 | 0.76 | 14 | Plot 6 | 3 | 80 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.74 | 0.89 | 14 | Plot 11 | 2 | 559 | Plot 11: missing LAI data |
| **Log R** | **none** | 7.19.04 | 0.74 | 0.62 | 14 | Plot 8 | 3 | 91 | Plot 8: high LAI |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.73 | 0.61 | 14 | Plot 7 | 4 | 57 | Plot 7: low LAI |
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.72 | 0.62 | 14 | Plot 7 | 2 | 51 | Plot 7: low LAI |
| **Norris 1st Derivative** | **Log LAI** | 7.19.04 | 0.72 | 0.05 | 14 | Plot 7 | 2 | 37 | Plot 7: low LAI |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.69 | 0.93 | 14 | Plot 6 | 5 | 30 | Plot 6: high reflectance |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.69 | 0.84 | 15 | none | 1 | 13 | none |
| **Absorbance Transformation** | **none** | 7.19.04 | 0.68 | 0.68 | 13 | Plots 8, 10 | 4 | 9 | Plot 8: high LAI; Plot 10: high absorbance |
| **Untransformed (350-1075nm)** | **Log (base 10) LAI** | 7.19.04 | 0.67 | 0.07 | 14 | Plot 8 | 4 | 21 | Plot 8: high LAI |
| **Norris 1st Derivative** | **Log LAI** | 8.02.05 | 0.66 | 0.08 | 14 | Plot 10 | 1 | 33 | Plot 10: low LAI |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 7.19.04 | 0.65 | 0.05 | 14 | Plot 7 | 1 | 16 | Plot 7: low LAI |

| Spectra Transformations | LAI Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Kubelka-Munk Transformation** | **none** | 7.19.04 | 0.65 | 0.81 | 15 | none | 2 | 11 | none |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 8.24.04 | 0.65 | 0.07 | 15 | none | 1 | 15 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.63 | 0.68 | 14 | Plot 7 | 1 | 17 | Plot 7: low LAI |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.60 | 0.70 | 14 | Plot 7 | 3 | 28 | Plot 7: low LAI |
| **Log R** | **Square root LAI** | 8.24.04 | 0.60 | 0.20 | 14 | Plot 6 | 8 | 11 | Plot 6: high reflectance |
| **Transform 1/R** | **none** | 8.24.04 | 0.56 | 1.03 | 14 | Plot 6 | 9 | 14 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.53 | 1.20 | 14 | Plot 5 | 5 | 6 | Plot 5: high reflectance |
| **Norris 1st Derivative** | **Log LAI** | 8.24.04 | 0.53 | 0.08 | 14 | Plot 6 | 1 | 74 | Plot 6: high reflectance |
| **Untrans. spectra, manual test set** | **none** | 8.24.04 | 0.52 | 1.12 | 5 | none | 6 | none | Remaining plots used in the calibration set |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.48 | 1.02 | 14 | Plot 6 | 1 | 88 | Plot 6: high reflectance |
| **Untrans. spectra, random test set** | **none** | 8.24.04 | 0.38 | 0.79 | 5 | Plot 6 | 2 | none | Remaining used in the cal. set; Plot 6: high refl |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.12 | 0.61 | 14 | Plot 10 | 1 | 24 | Plot 10: low reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.08 | 1.02 | 14 | Plot 8 | 1 | none | Plot 8: low reflectance |
| **PLS2 Untransformed (325-1075nm)** | **LAI, Species, Diver.** | 7.19.04 | -0.21 | 0.99 | 14 | Plot 7 | 1 | none | Plot 7: low LAI |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | -0.48 | 0.93 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | -0.69 | 0.80 | 15 | none | 1 | none | none |

**Table C17. PLS-regressions for LAI at the *Phragmites*-absent (PA) site. r = regression coefficient, RMSEP = root mean square error of prediction, PCs = PLS-components**

| Spectra Transformations | LAI Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untrans. spectra, manual test set** | **none** | 8.24.04 | 0.95 | 1.54 | 5 | none | 5 | none | Remainder used in calibration |
| **Untrans. spectra, random test set** | **none** | 8.24.04 | 0.87 | 0.98 | 5 | none | 2 | none | Remainder used in calibration |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 8.24.04 | 0.83 | 0.06 | 15 | none | 2 | 46 | none |
| **Norris 1st Derivative** | **none** | 8.02.05 | 0.81 | 0.84 | 14 | Plot 3 | 2 | 154 | Plot 3: high reflectance |
| **Normalized spectra (R/R410)** | **none** | 7.19.04 | 0.80 | 0.70 | 15 | none | 4 | 409 | none |
| **Untransformed (350-1075nm)** | **none** | 8.24.04 | 0.79 | 0.76 | 14 | Plot 1 | 2 | 445 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | **Arcsine sqrt (LAI)** | 7.19.04 | 0.78 | 0.02 | 15 | none | 5 | 144 | none |
| **Untransformed (350-1075nm)** | **4th root LAI** | 7.19.04 | 0.78 | 0.06 | 15 | none | 5 | 143 | none |
| **Untransformed (350-1075nm)** | **Square root LAI** | 7.19.04 | 0.78 | 0.18 | 15 | none | 5 | 144 | none |
| **Log R** | **none** | 7.19.04 | 0.78 | 0.74 | 15 | none | 4 | 174 | none |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 7.19.04 | 0.76 | 0.07 | 15 | none | 1 | 37 | none |
| **Transform 1/R** | **none** | 8.24.04 | 0.76 | 0.80 | 14 | Plot 1 | 2 | 418 | Plot 1: high reflectance |
| **Log R** | **Square root LAI** | 8.24.04 | 0.76 | 0.18 | 15 | none | 3 | 29 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 7.19.04 | 0.75 | 0.78 | 15 | none | 1 | 31 | none |
| **Truncated spectra (400-950nm)** | **none** | 8.24.04 | 0.75 | 0.82 | 14 | Plot 1 | 2 | 333 | Plot 1: high reflectance |
| **Golay 2nd Derivative, avg 10** | **Log LAI** | 9.21.04 | 0.75 | 0.10 | 14 | Plot 5 | 1 | 31 | Plot 5: high LAI |
| **Untransformed (350-1075nm)** | **none** | 7.19.04 | 0.73 | 0.76 | 13 | Plots 6, 15 | 2 | 173 | Plots 6, 15: high reflectance |
| **MSC Transformation** | **none** | 7.19.04 | 0.72 | 0.81 | 15 | none | 2 | 165 | none |
| **Absorbance Transformation** | **none** | 7.19.04 | 0.72 | 0.84 | 15 | none | 3 | 179 | none |
| **Untransformed (350-1075nm)** | **Log (base 10) LAI** | 7.19.04 | 0.71 | 0.07 | 15 | none | 2 | 176 | none |
| **Transform 1/R** | **Arcsine sqrt (LAI)** | 7.19.04 | 0.71 | 0.02 | 15 | none | 2 | 154 | none |
| **Transform 1/R** | **none** | 7.19.05 | 0.71 | 0.82 | 15 | none | 2 | 161 | none |
| **Untransformed (350-1075nm)** | **none** | 8.02.05 | 0.71 | 0.70 | 15 | none | 2 | 555 | none |
| **Golay 2nd Derivative, avg 10** | **none** | 8.24.04 | 0.71 | 0.87 | 15 | none | 2 | 89 | none |
| **Log R** | **Square root LAI** | 7.19.04 | 0.70 | 0.19 | 15 | none | 4 | 168 | none |

| Spectra Transformations | LAI Transformations | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Norris 1st Derivative** | **none** | 7.19.04 | 0.68 | 0.86 | 15 | none | 2 | 57 | none |
| **Norris 1st Derivative** | **Log LAI** | 7.19.04 | 0.68 | 0.08 | 15 | none | 2 | 62 | none |
| **Norris 1st Derivative** | **Log LAI** | 8.24.04 | 0.68 | 0.08 | 14 | Plot 1 | 1 | 215 | Plot 1: high reflectance |
| **Golay 1st Derivative** | **none** | 8.24.04 | 0.67 | 0.92 | 14 | Plot 1 | 1 | 237 | Plot 1: high reflectance |
| **Golay 1st Derivative** | **none** | 7.19.04 | 0.65 | 0.89 | 15 | none | 2 | 73 | none |
| **Truncated spectra (400-950nm)** | **none** | 7.19.04 | 0.64 | 0.64 | 14 | Plot 6 | 7 | 421 | Plot 6: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 5.25.04 | 0.60 | 0.88 | 14 | Plot 5 | 4 | 39 | Plot 5: missing reflectance |
| **Kubelka-Munk Transformation** | **none** | 7.19.04 | 0.55 | 0.98 | 15 | none | 2 | 230 | none |
| **PLS2 Untransformed (325-1075nm)** | **LAI, species, diver.** | 7.19.04 | 0.55 | 1.04 | 15 | none | 3 | 196 | none |
| **Untransformed (350-1075nm)** | **none** | 6.29.04 | 0.47 | 0.84 | 14 | Plot 5 | 2 | 321 | Plot 5: high LAI |
| **Untransformed (350-1075nm)** | **none** | 9.21.04 | 0.31 | 0.57 | 14 | Plot 5 | 1 | 96 | Plot 5: high LAI |
| **Untransformed (350-1075nm)** | **none** | 6.06.05 | 0.24 | 1.12 | 13 | Plots 1,3 | 1 | 160 | Plots 1,3: high reflectance |
| **Untransformed (350-1075nm)** | **none** | 6.16.04 | 0.06 | 1.01 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | **none** | 6.03.04 | 0.01 | 0.94 | 11 | Plots 8,9,10,14 | 1 | none | Plots 8,10,14: no LAI data; Plot 9: no reflect. |

**Table C18. PLS-regressions transformations tested on spectra and LAI. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Truncated spectra (400-950 nm) | Arcsine sqrt (LAI) | 4th root LAI | Sqrt (LAI) | $Log_{10}$ LAI | Manual test set | Random test set | Normalized spectra | Transform 1/R | Transform 1/R, Arcsine sqrt (LAI) | Log R | Log R, Sqrt (LAI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | PD site and PA site | | | | | | | | | | | | |
| 6/3/2004 | PD, PA | | | | | | | | | | | | |
| 6/16/2004 | PD, PA | | | | | | | | | | | | |
| 6/29/2004 | PD, PA | | | | | | | | | | | | |
| 7/19/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | | | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA |
| 8/24/2004 | PD, PA | PD, PA | | | | | PD, PA | PD, PA | | PD, PA | | | PD, PA |
| 9/21/2004 | PD, PA | | | | | | | | | | | | |
| 6/6/2005 | PD, PA | | | | | | | | | | | | |
| 8/2/2005 | PD, PA | | | | | | | | | | | | |

| | Norris 1st Derivative | Norris 1st Deriv, Log (LAI) | Golay 1st Derivative | Golay 2nd Derivative | Golay 2nd Derivative, Log (LAI) | MSC Transform | Absorbance Transform | Kubelka-Munk Transform |
|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | | | | | | | | |
| 6/3/2004 | | | | | | | | |
| 6/16/2004 | | | | | | | | |
| 6/29/2004 | | | | | | | | |
| 7/19/2004 | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA | PD, PA |
| 8/24/2004 | | PD, PA | PD, PA | PD, PA | PD, PA | | | |
| 9/21/2004 | | | | | PD, PA | | | |
| 6/6/2005 | | | | | | | | |
| 8/2/2005 | PA | PD | | | | | | |

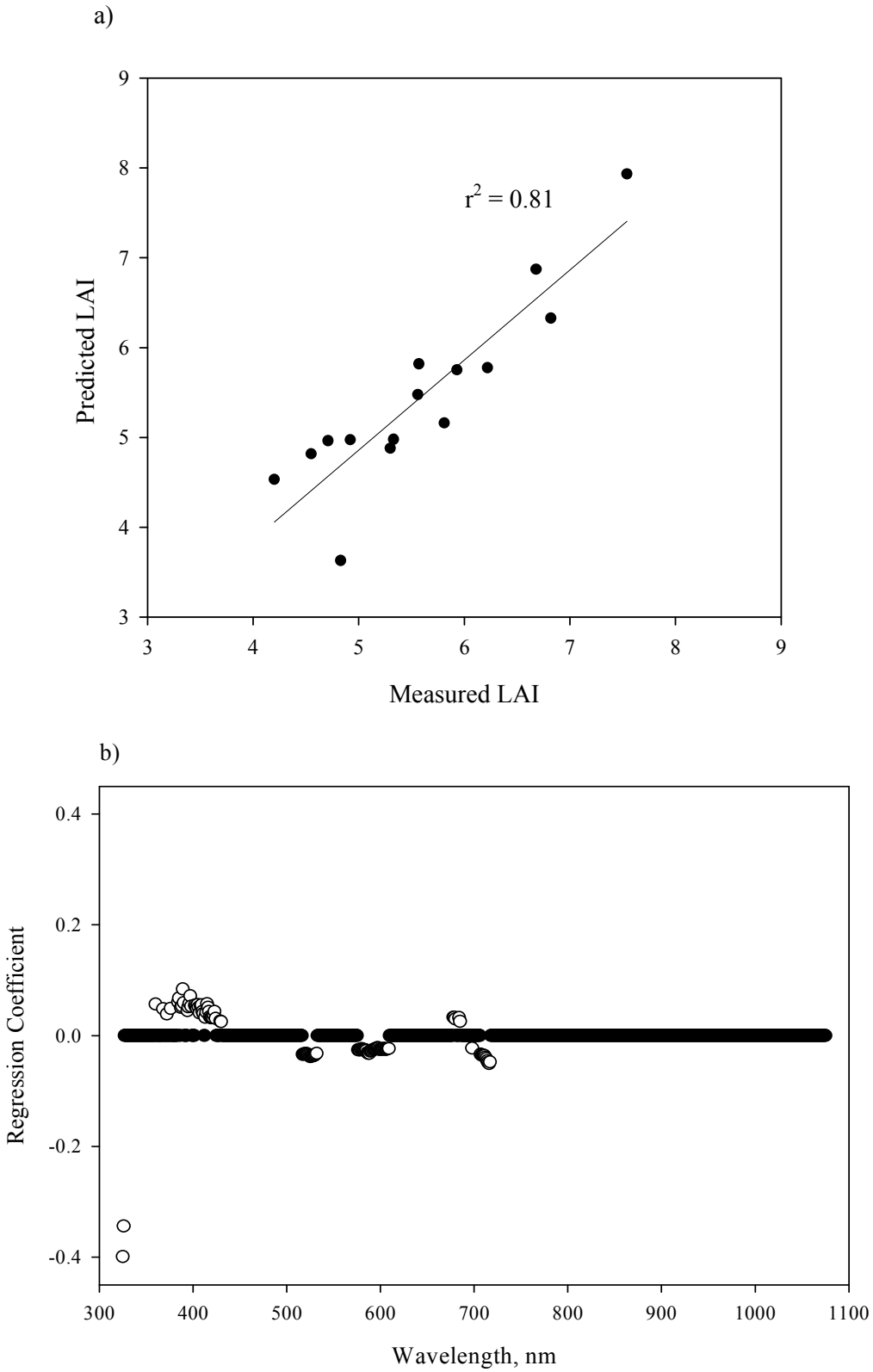



**Figure C28. (a) Predicted vs measured LAI PLS-regression at the *Phragmites*-dominant site on 6/16/04 using 107 untransformed spectral bands that were combined into ten PLS-components with an RMSEP of 0.46% and r = 0.90. (b) Loading plot of regression coefficients for the PLS-regression where spectral bands used in the regression are depicted by open circles.**

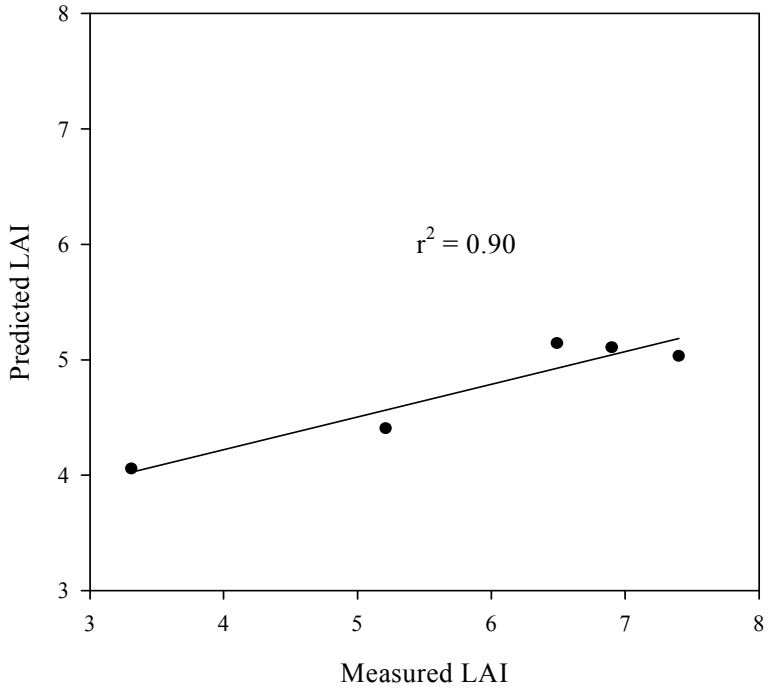



**Figure C29. Predicted vs measured LAI PLS-regression at the *Phragmites*-absent site on 8/24/04 using test set validation with five PLS-components and an RMSEP of 1.5% and r = 0.95.**

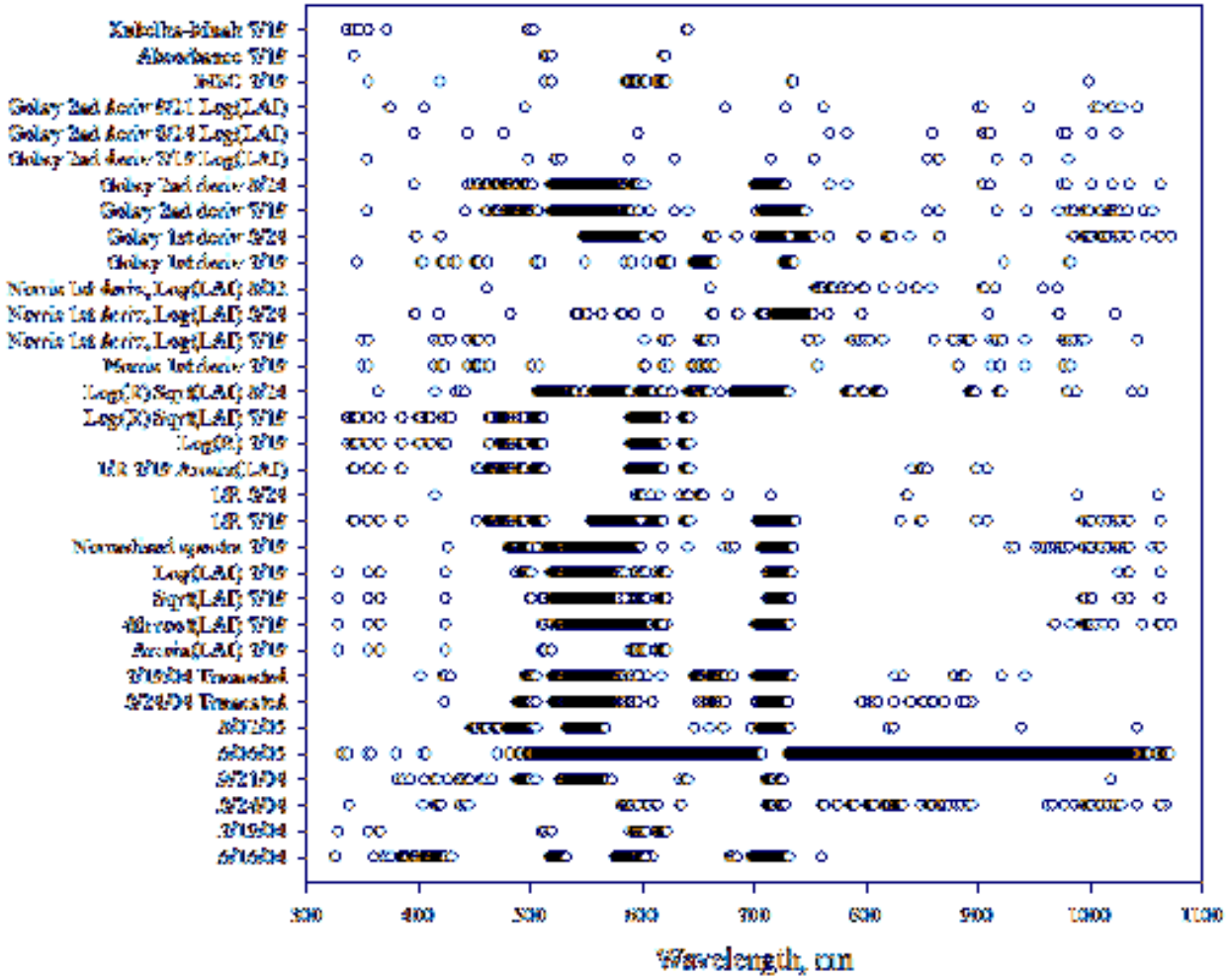



**Figure C30. Significant spectral bands for LAI according to PLS-regressions at the *Phragmites*-dominant site.**

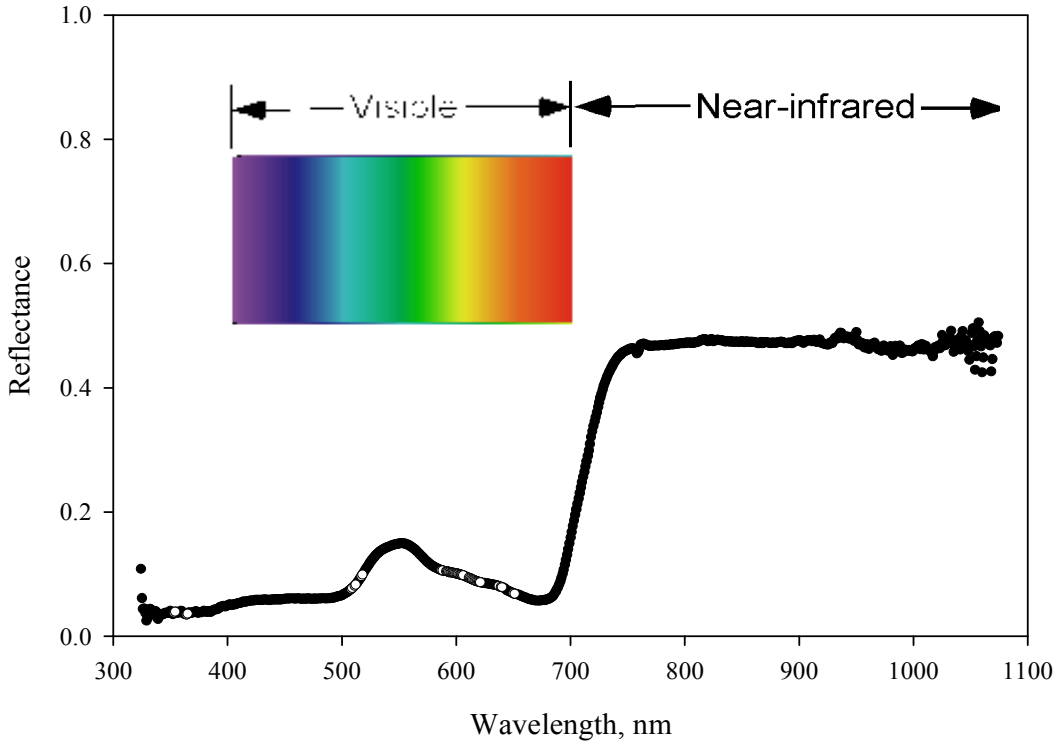



**Figure C31. Spectral bands significant for seven or more regressions for LAI at the *Phragmites*-dominant site are indicated by an open circle.**

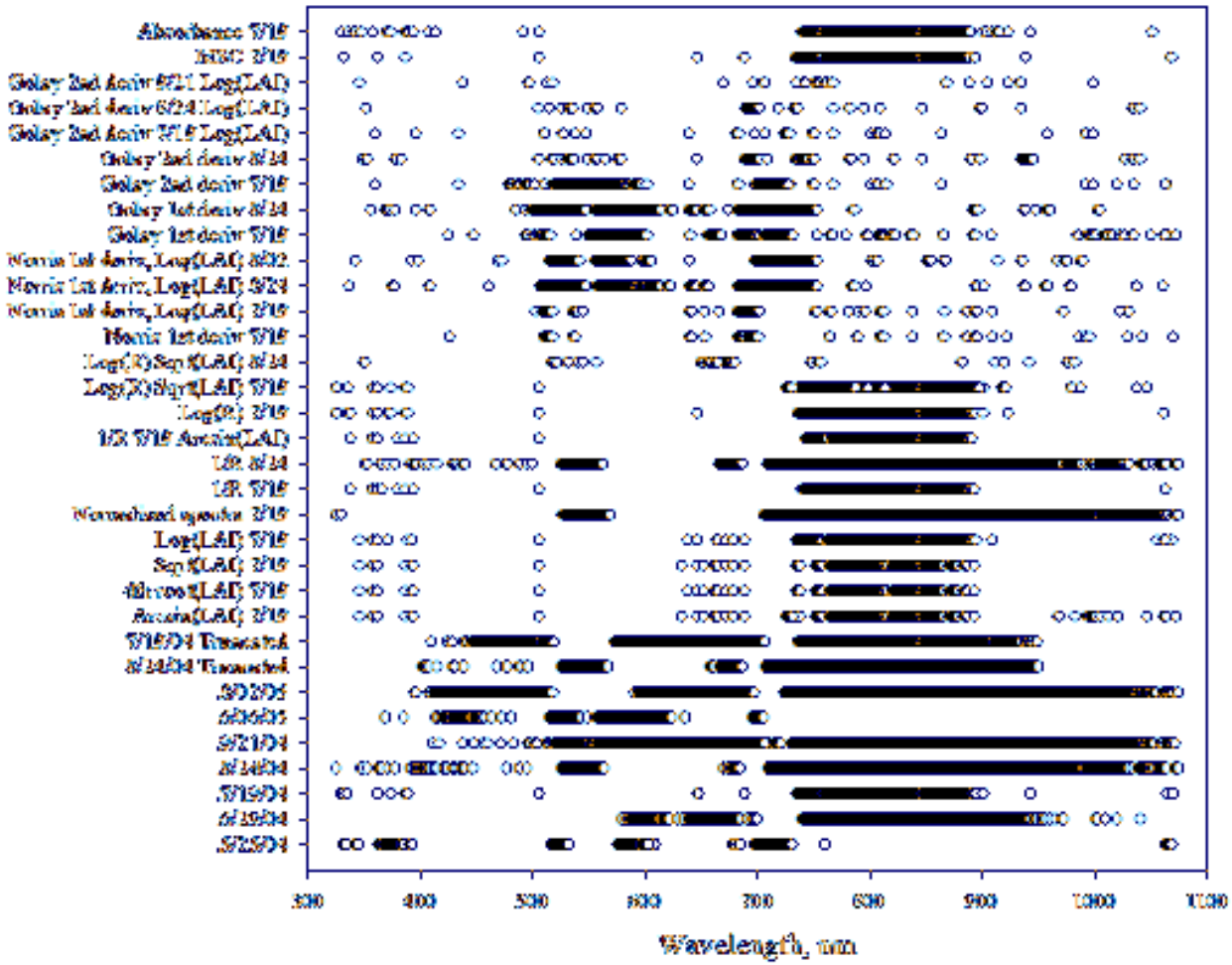



**Figure C32. Significant spectral bands for LAI according to PLS-regressions at the *Phragmites*-absent site.**

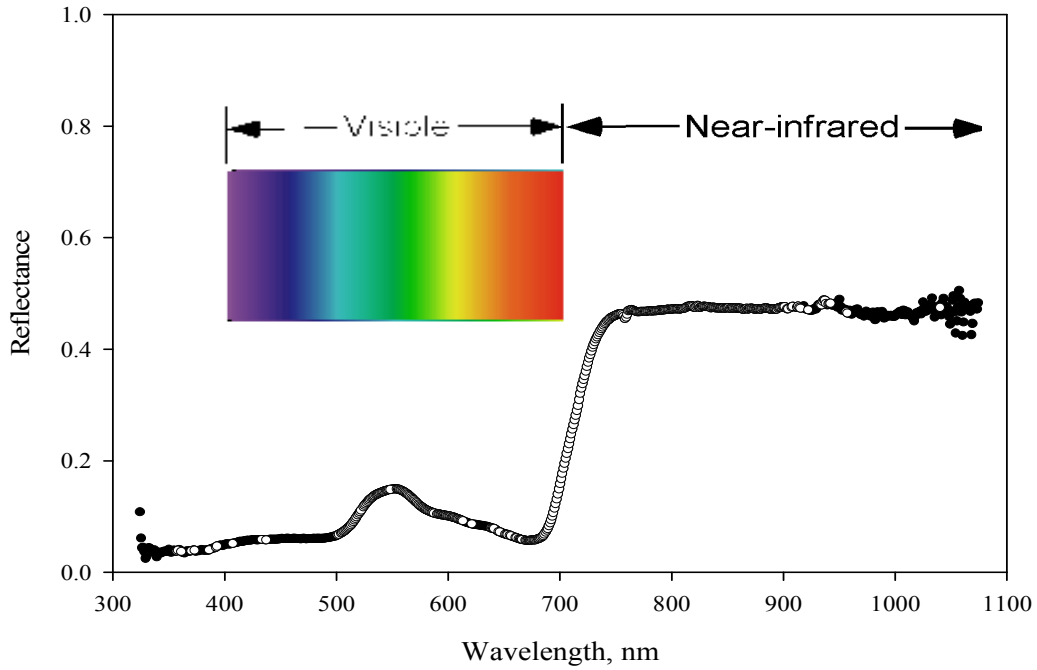



**Figure C33. Spectral bands significant for seven or more regressions for LAI at the *Phragmites*-absent site are indicated by an open circle.**

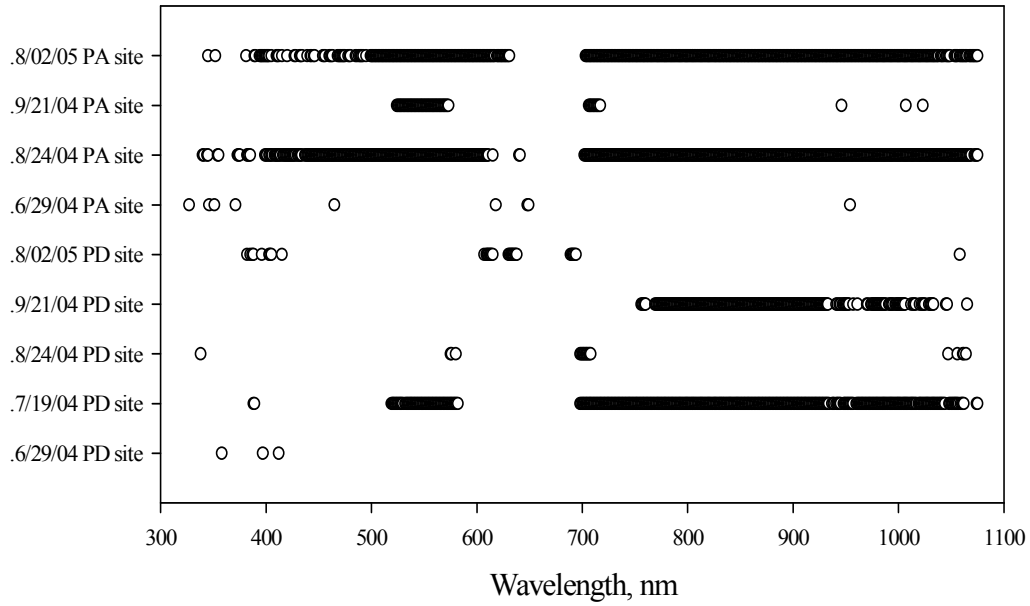



**Figure C34. Significant spectral bands for species richness according to PLS-regressions at the *Phragmites*-dominant (PD) site and the *Phragmites*-absent (PA) site.**

**Table C19. PLS-regressions for species richness on data from both the *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites.**

| Spectra Transformations | Marsh Site | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.29.04 | 0.56 | 0.78 | 14 | Plot 10 | 1 | 9 | Plot 10: many species |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.02.05 | 0.53 | 1.08 | 15 | none | 5 | 555 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 7.19.04 | 0.43 | 1.30 | 14 | Plot 10 | 2 | 420 | Plot 10: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 5.25.04 | 0.42 | 1.81 | 11 | Plots 1-3, 12 | 2 | none | Plots 1-3: missing refl; Plot 12: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.24.04 | 0.41 | 0.95 | 15 | none | 1 | 595 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 9.21.04 | 0.41 | 0.86 | 15 | none | 1 | 65 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.02.05 | 0.39 | 1.28 | 14 | Plot 12 | 1 | 33 | Plot 12: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 9.21.04 | 0.32 | 1.14 | 14 | Plot 5 | 2 | 232 | Plot 5: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.24.04 | 0.26 | 1.28 | 14 | Plot 5 | 1 | 20 | Plot 5: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.29.04 | 0.24 | 1.04 | 14 | Plot 11 | 6 | 3 | Plot 11: few species present |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 5.25.04 | 0.15 | 1.14 | 14 | Plot 10 | 1 | none | Plot 10: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 7.19.04 | 0.12 | 1.91 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.16.04 | -0.01 | 1.23 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.06.05 | -0.03 | 1.55 | 14 | Plot 3 | 1 | none | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.03.04 | -0.06 | 1.38 | 13 | Plots 9,10 | 1 | none | Plot 9: no reflect.; Plot 10: no species data |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.03.04 | -0.22 | 1.87 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.16.04 | -0.54 | 2.19 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.06.05 | -0.68 | 1.99 | 15 | none | 1 | none | none |

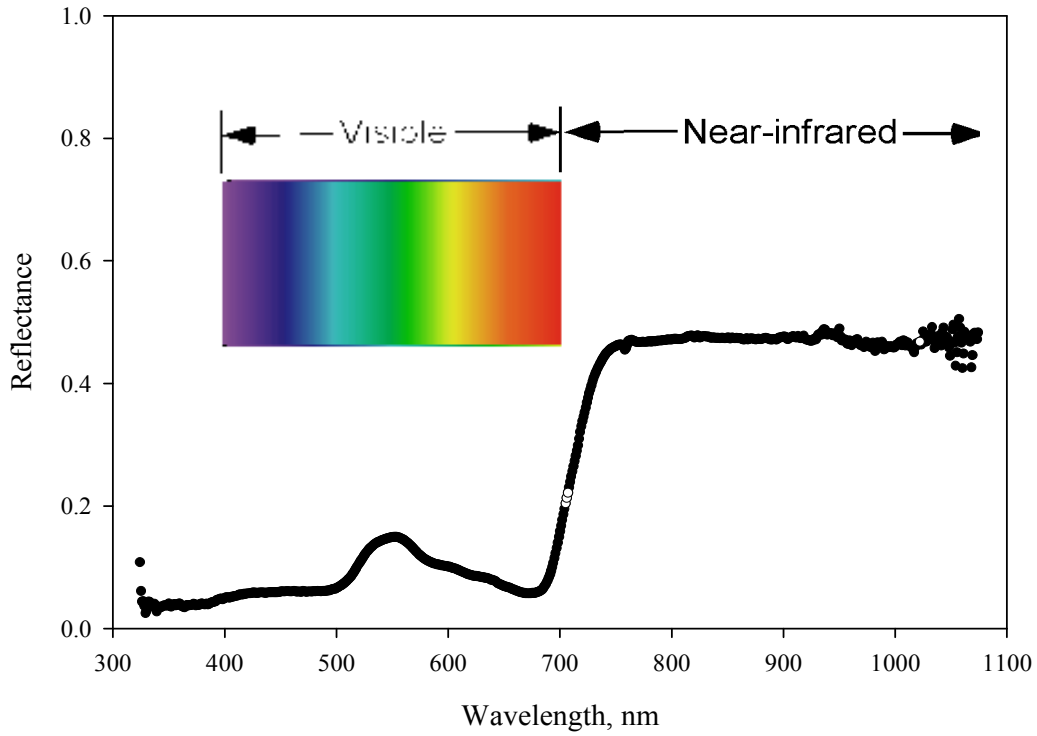



**Figure C35. Spectral bands significant for five or more regressions for species richness at the *Phragmites*-dominant (PD) site and the *Phragmites*-absent (PA) site are indicated by an open circle.**

**Table C20. PLS-regressions for diversity index on data from both the *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites.**

| Spectra Transformations | Marsh Site | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 9.21.04 | 0.84 | 0.25 | 15 | none | 8 | 207 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.24.04 | 0.83 | 0.22 | 15 | none | 5 | 385 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 8.24.04 | 0.81 | 0.23 | 15 | none | 2 | 104 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.02.05 | 0.80 | 0.21 | 15 | none | 2 | 609 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 5.25.04 | 0.70 | 0.21 | 15 | none | 5 | 65 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.03.04 | 0.68 | 0.22 | 15 | none | 3 | 261 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.06.05 | 0.65 | 0.10 | 13 | Plots 2,10 | 3 | 17 | Plot 2: high reflectance; Plot 10: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 7.19.04 | 0.65 | 0.14 | 15 | none | 2 | 10 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.29.04 | 0.64 | 0.21 | 14 | Plot 6 | 3 | 35 | Plot 6: low reflectance |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 7.19.04 | 0.62 | 0.27 | 14 | Plot 13 | 1 | 74 | Plot 13: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 7.19.04 | 0.59 | 0.28 | 14 | Plot 13 | 2 | 494 | Plot 13: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.24.04 | 0.54 | 0.22 | 15 | none | 1 | 411 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 9.21.04 | 0.53 | 0.40 | 14 | Plot 11 | 1 | 49 | Plot 11: high reflectance |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 8.24.04 | 0.49 | 0.23 | 15 | none | 1 | 58 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 5.25.04 | 0.46 | 0.14 | 11 | Plot 1-3, 6 | 2 | 146 | Plots 1-3: missing reflectance; Plot 6: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.02.05 | 0.44 | 0.24 | 14 | Plot 5 | 3 | 48 | Plot 5: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.06.05 | 0.39 | 0.26 | 14 | Plot 3 | 2 | 32 | Plot 3: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.03.04 | 0.35 | 0.35 | 13 | Plots 9,10 | 3 | none | Plot 9: missing refl.; Plot 10: missing veg data |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.29.04 | 0.15 | 0.25 | 15 | none | 1 | 75 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 7.19.04 | 0.07 | 0.20 | 14 | Plot 1 | 1 | 8 | Plot 1: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.16.04 | 0.03 | 0.18 | 13 | Plots 5,14 | 1 | none | Plot 5: high reflectance; Plot 14: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.16.04 | 0.01 | 0.13 | 14 | Plot 11 | 1 | 24 | Plot 11: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 9.21.04 | -0.19 | 0.21 | 15 | none | 1 | none | none |

**Table C21. Transformations performed on data for the diversity index PLS-regressions. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Golay 2nd Derivative |
|---|---|---|
| 5/25/2004 | PD site and PA site | |
| 6/3/2004 | PD, PA | |
| 6/16/2004 | PD, PA | |
| 6/29/2004 | PD, PA | |
| 7/19/2004 | PD, PA | PD, PA |
| 8/24/2004 | PD, PA | PD, PA |
| 9/21/2004 | PD, PA | PA |
| 6/6/2005 | PD, PA | |
| 8/2/2005 | PD, PA | |

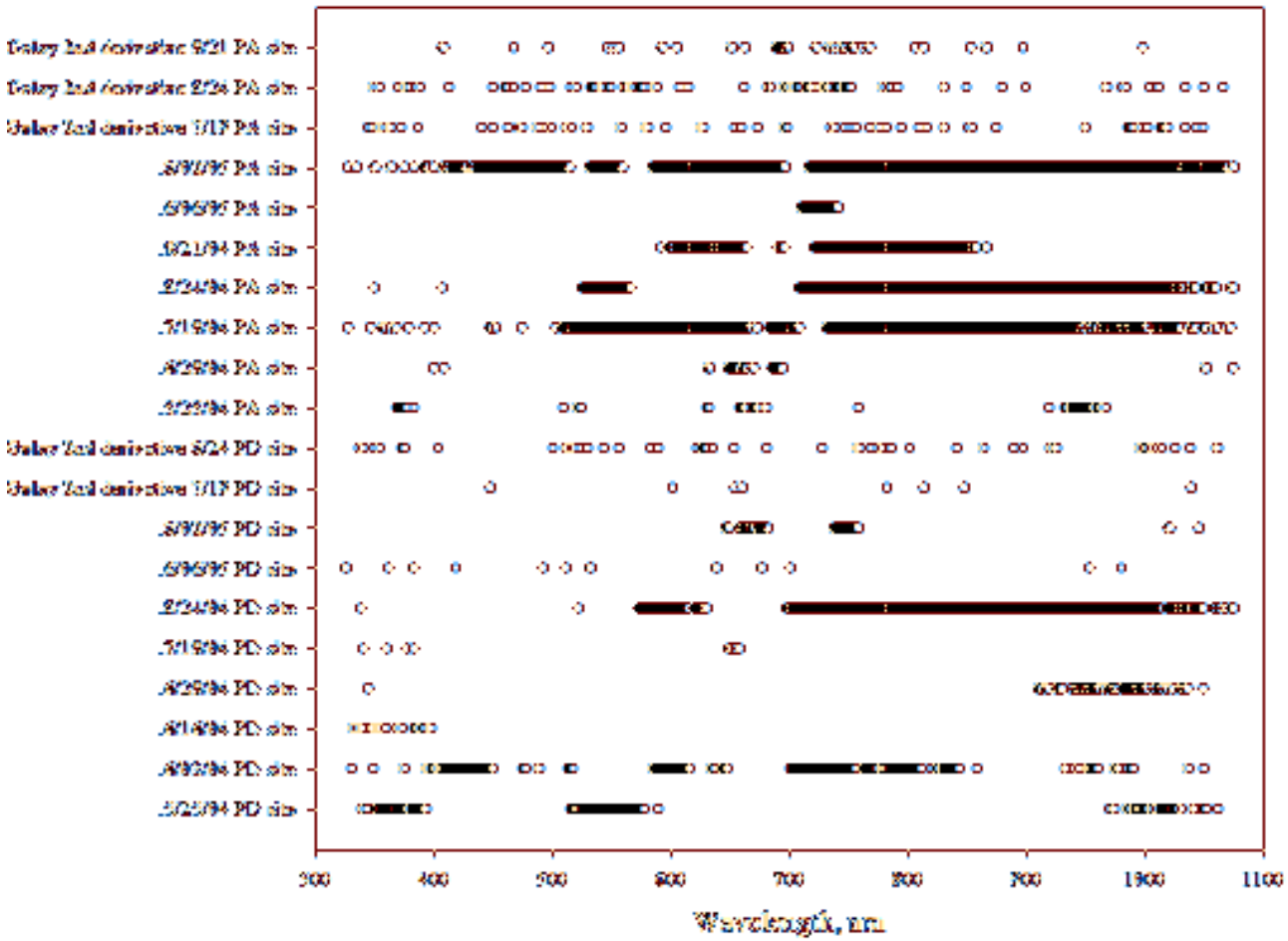


**Figure C36. Significant spectral bands for species diversity index according to PLS-regressions for both the *Phragmites*-dominant (PD) and the *Phragmites*-absent (PA) sites.**

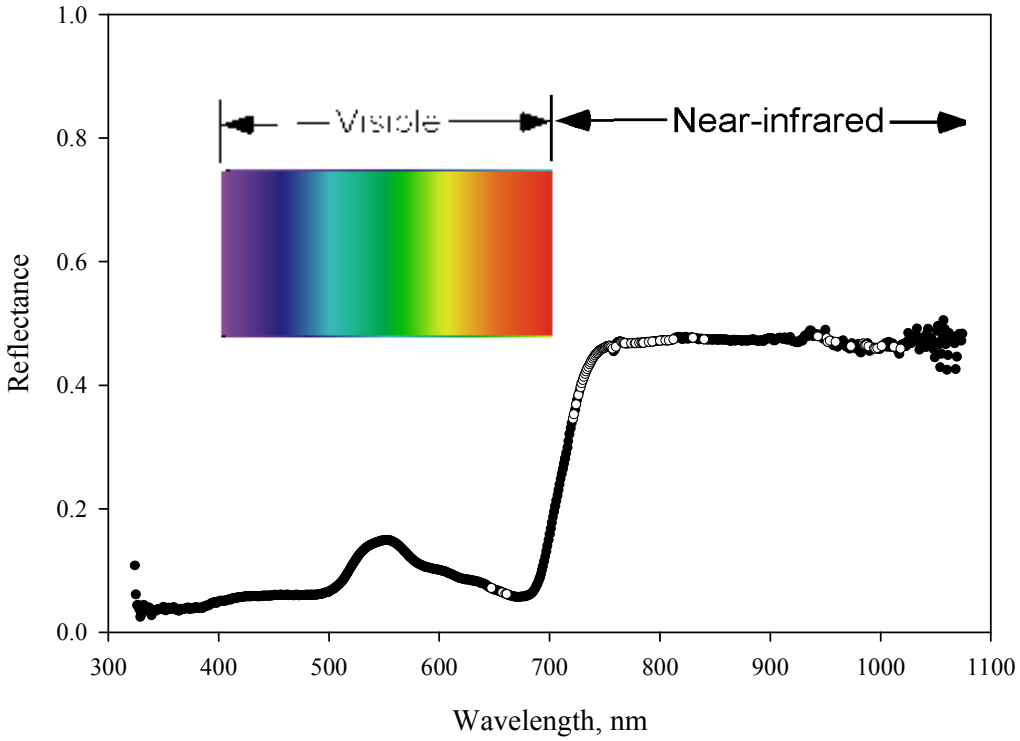



**Figure C37. Spectral bands significant for seven or more regressions for diversity index at the *Phragmites*-dominant (PD) site and the *Phragmites*-absent (PA) site are indicated by an open circle.**

**Table C22. PLS-regressions for percent cover of dead material on data from both the *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites.**

| Spectra Transformations | Marsh Site | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 5.25.04 | 0.92 | 2.00 | 14 | Plot 6 | 3 | 165 | Plot 6: high dead material conc. |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 9.21.04 | 0.82 | 15.25 | 14 | Plot 12 | 6 | 34 | Plot 12: low reflectance |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 8.24.04 | 0.77 | 9.35 | 15 | none | 1 | 26 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 9.21.04 | 0.77 | 12.04 | 14 | Plot 7 | 2 | 168 | Plot 7: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 5.25.04 | 0.73 | 7.35 | 12 | Plot 1-3 | 2 | 93 | Plots 1-3: missing reflectance |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 7.19.04 | 0.68 | 0.17 | 15 | none | 1 | 47 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.03.04 | 0.65 | 0.78 | 13 | Plot 3, 7 | 2 | 20 | Plot 3: high refl; Plot 7: high dead conc. |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 9.21.04 | 0.64 | 21.28 | 14 | Plot 12 | 1 | 37 | Plot 12: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 7.19.04 | 0.61 | 0.19 | 15 | none | 2 | 531 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.02.05 | 0.58 | 0.45 | 15 | none | 8 | 124 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.24.04 | 0.52 | 0.82 | 15 | none | 2 | 404 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 8.24.04 | 0.52 | 0.82 | 15 | none | 1 | 17 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.24.04 | 0.42 | 13.53 | 15 | none | 2 | 315 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.16.04 | 0.33 | 1.31 | 13 | Plots 5,14 | 2 | 49 | Plot 5: high refl; Plot 14: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.03.04 | 0.17 | 1.17 | 13 | Plots 9,10 | 1 | 9 | Plot 9: missing refl.; Plot 10: no veg data |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 7.19.04 | -0.01 | 2.87 | 14 | Plot 5 | 1 | none | Plot 5: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.02.05 | -0.10 | 2.76 | 14 | Plot 5 | 1 | none | Plot 5: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.16.04 | -0.43 | 12.73 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.29.04 | -0.54 | 1.08 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.29.04 | -0.69 | 2.75 | 15 | none | 1 | none | none |

**Table C23. Transformations performed on data for percent dead material PLS-regressions. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Golay 2nd Derivative |
|---|---|---|
| 5/25/2004 | PD site and PA site | |
| 6/3/2004 | PD, PA | |
| 6/16/2004 | PD, PA | |
| 6/29/2004 | PD, PA | |
| 7/19/2004 | PD, PA | PA |
| 8/24/2004 | PD, PA | PD, PA |
| 9/21/2004 | PD, PA | PD |
| 6/6/2005 | PD, PA | |
| 8/2/2005 | PD, PA | |

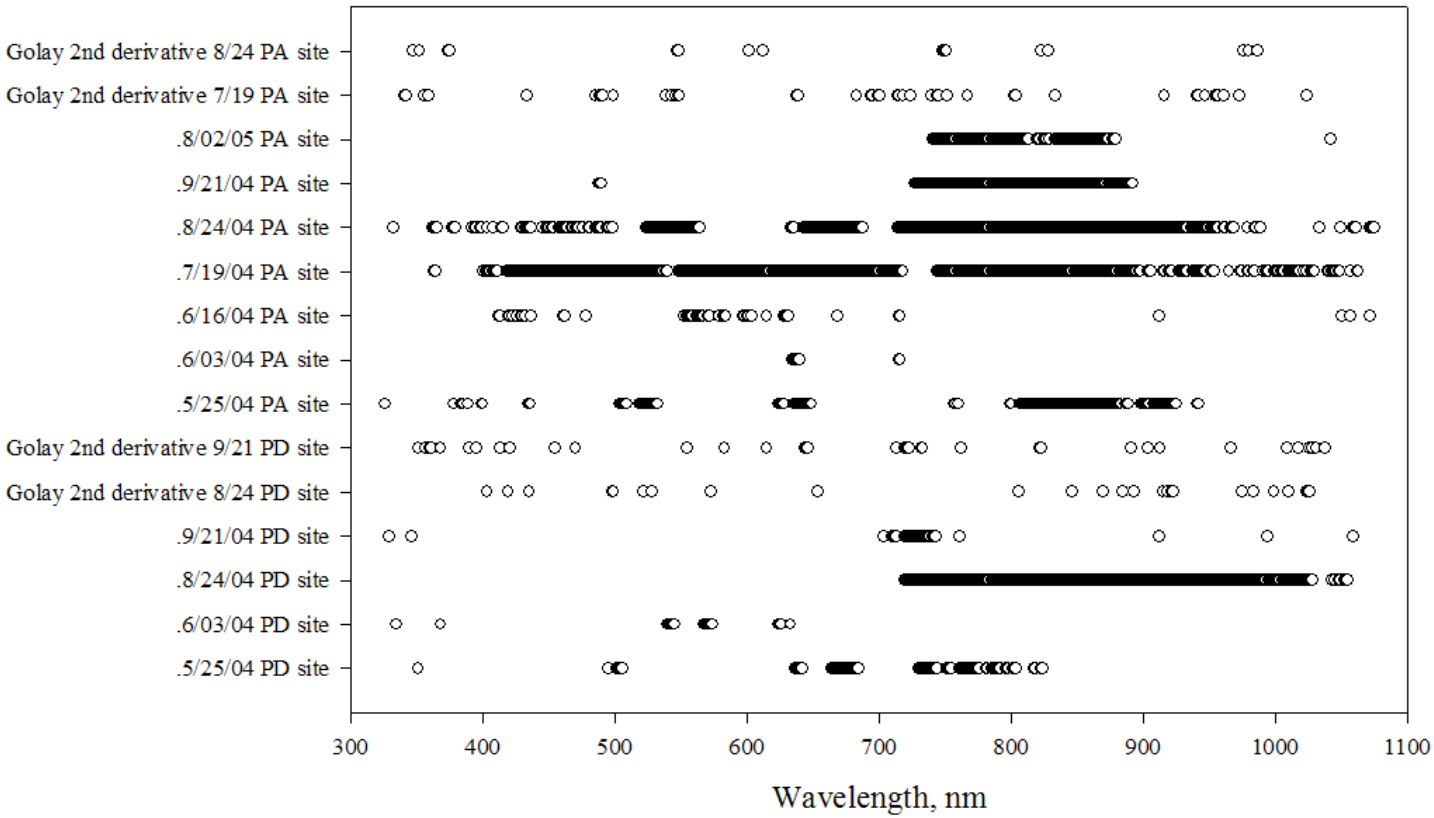



**Figure C38. Significant spectral bands for percent dead material according to PLS-regressions for both the *Phragmites*-dominant (PD) and the *Phragmites*-absent (PA) sites.**

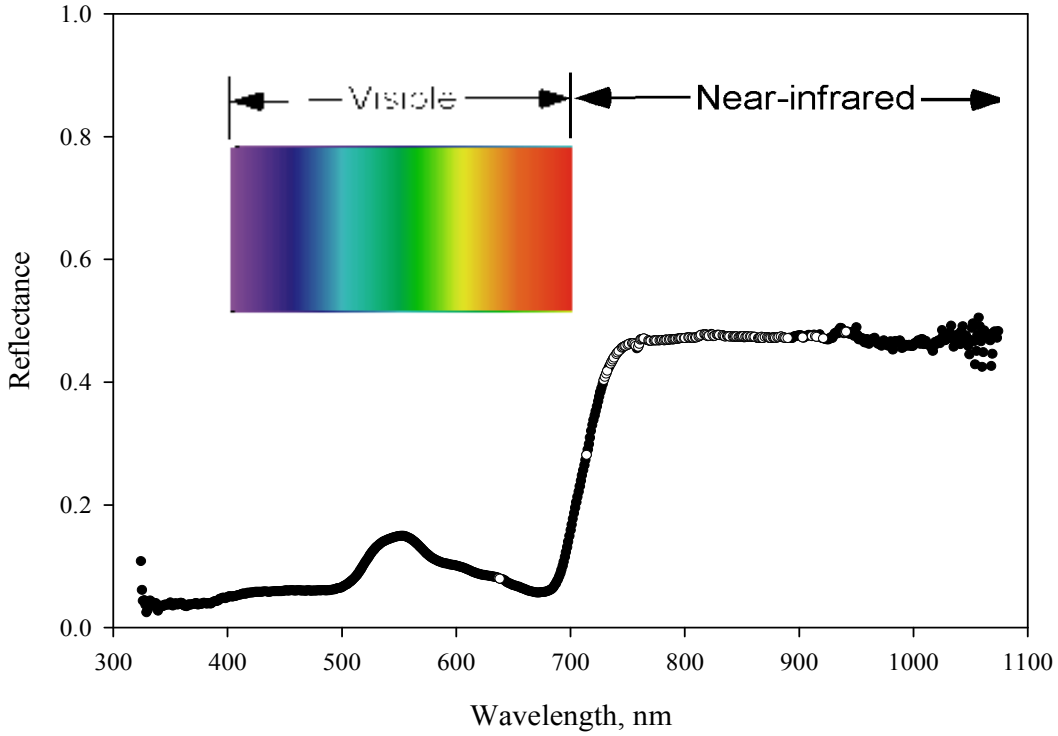



**Figure C39. Spectral bands significant for five or more regressions for percent dead material at the *Phragmites*-dominant (PD) site and the *Phragmites*-absent (PA) site are indicated by an open circle.**

**Table C24. PLS-regressions for percent exposed soil on data from both the *Phragmites*-dominant (PD) and *Phragmites*-absent (PA) sites.**

| Spectra Transformations | Marsh Site | Date | r | RMSEP | n | Name of plots removed | PCs | # bands used | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.24.04 | 0.97 | 3.62 | 15 | none | 6 | 351 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 7.19.04 | 0.91 | 0.53 | 15 | none | 2 | 88 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.29.04 | 0.82 | 1.28 | 15 | none | 3 | 118 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 7.19.04 | 0.76 | 0.83 | 15 | none | 2 | 150 | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-absent** | 6.29.04 | 0.75 | 1.49 | 15 | none | 1 | none | none |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 8.24.04 | 0.71 | 11.25 | 14 | Plot 14 | 1 | 20 | Plot 14: noisy derivative of reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.02.05 | 0.65 | 0.77 | 14 | Plot 4 | 4 | 78 | Plot 4: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 5.25.04 | 0.63 | 1.56 | 15 | none | 6 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.03.04 | 0.61 | 0.43 | 13 | Plots 9,10 | 4 | 8 | Plot 9: missing refl.; Plot 10: no veg data |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 6.16.04 | 0.56 | 1.44 | 14 | Plot 2 | 3 | 431 | Plot 2: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 9.21.04 | 0.56 | 10.34 | 15 | none | 1 | 138 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 5.25.04 | 0.41 | 2.51 | 11 | Plots 1-3,6 | 1 | 171 | Plots 1-3: missing refl; Plot 6: low refl |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.16.04 | 0.36 | 1.93 | 15 | none | 2 | 57 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.29.04 | 0.33 | 1.08 | 14 | Plot 12 | 1 | 2 | Plot 13: high reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 7.19.04 | 0.27 | 4.62 | 15 | none | 1 | 18 | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 9.21.04 | 0.15 | 15.29 | 14 | Plot 12 | 2 | 141 | Plot 12: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-absent** | 8.24.04 | 0.06 | 0.98 | 14 | Plot 6 | 1 | none | Plot 6: low reflectance |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 6.03.04 | -0.39 | 2.34 | 14 | Plot 3 | 1 | none | Plot 3: high reflectance |
| **Golay 2nd Derivative, avg 10** | ***Phragmites*-dominant** | 9.21.04 | -0.50 | 16.89 | 15 | none | 1 | none | none |
| **Untransformed (350-1075nm)** | ***Phragmites*-dominant** | 8.02.05 | -0.55 | 1.34 | 15 | none | 1 | none | none |

**Table C25 Transformations performed on data for percent exposed soil PLS-regressions. Site is identified as PD (*Phragmites*-dominant) or PA (*Phragmites*-absent).**

| | Untransformed (350-1075 nm) | Golay 2nd Derivative |
|---|---|---|
| 5/25/2004 | PD site and PA site | |
| 6/3/2004 | PD, PA | |
| 6/16/2004 | PD, PA | |
| 6/29/2004 | PD, PA | PA |
| 7/19/2004 | PD, PA | PA |
| 8/24/2004 | PD, PA | PD |
| 9/21/2004 | PD, PA | PD |
| 6/6/2005 | PD, PA | |
| 8/2/2005 | PD, PA | |

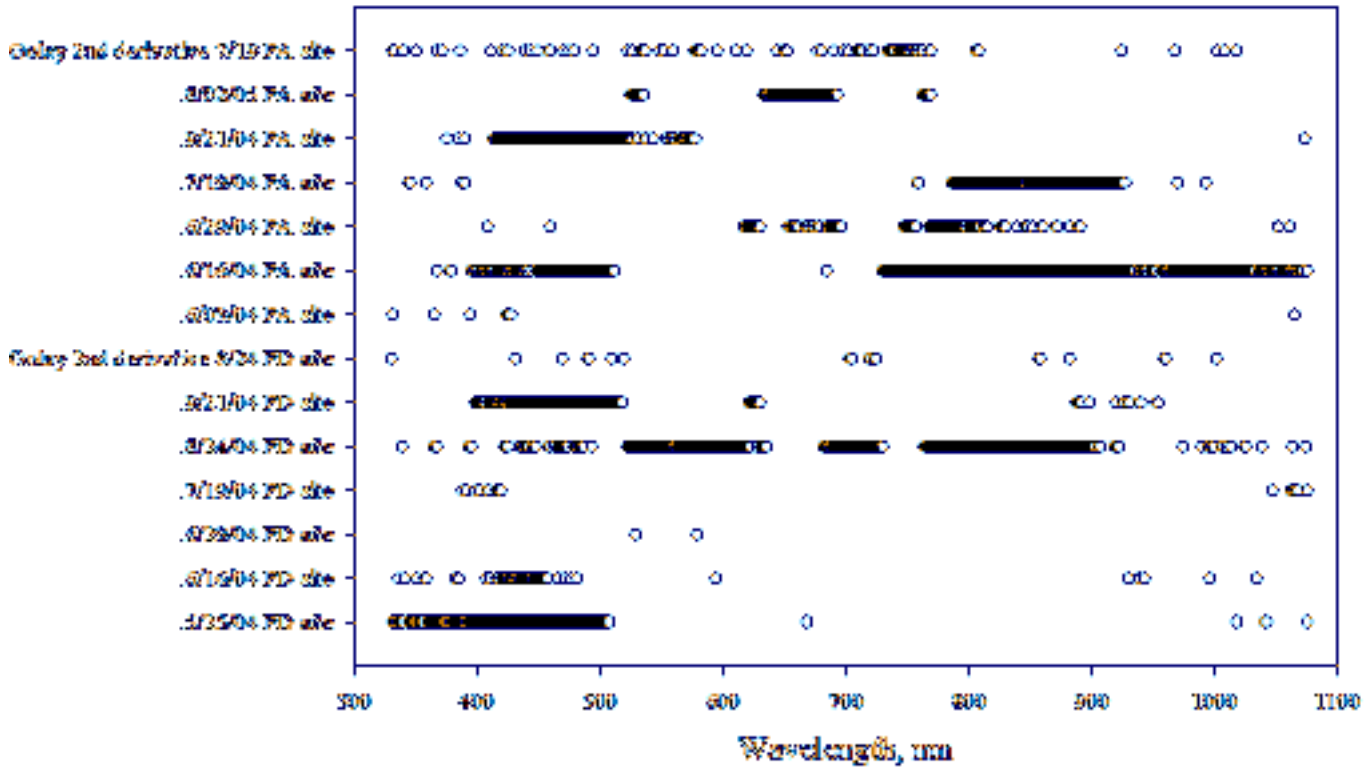



**Figure C40. Significant spectral bands for percent bare area according to PLS-regressions for both the *Phragmites*-dominant (PD) and the *Phragmites*-absent (PA) sites.**

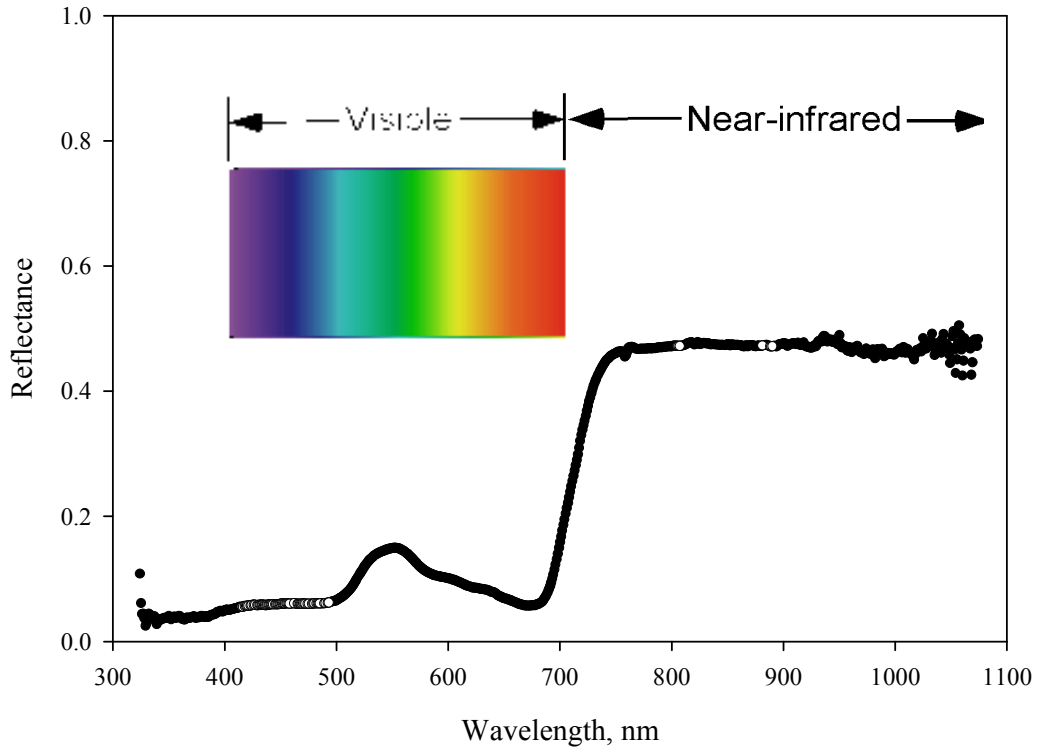



**Figure C41. Spectral bands significant for five or more regressions for percent bare area at the *Phragmites*-dominant (PD) site and the *Phragmites*-absent (PA) site are indicated by an open circle.**

## APPENDIX D Raw vegetation data across the 2004-05 seasons

LAI and species cover according to the Peet classification system are recorded for each plot on each sample date, as well as notes about each plot and time of day plot was observed.

**Table D1. Explanation of species abbreviations**

| Species Code | Species Name |
|---|---|
| TYSP | *Typha* species |
| PEVI | *Peltandra virginica* |
| HIMO | *Hibiscus moscheutos* |
| POAR | *Polygonum arifolium* |
| IMCA | *Impatiens capensis* |
| BILA | *Bidens laevis* |
| SISU | *Sium suave* |
| CIAR | *Cinna arundinacea* |
| LEOR | *Leersia oryzoides* |
| ZIAQ | *Zizania aquatica* |
| AMCA | *Amaranthus cannabinus* |
| BTS5B | *Bidens* species |
| SALA | *Sagittaria latifolia* |
| LIAR | *Limnophila aromatica* |
| ELOB | *Eleocharis obtusa* |
| SCTA | *Schoenoplectus tabernaemontani* |
| NULU | *Nuphar lutea* |
| ACCA | *Acorus calamus* |
| SCFL | *Schoenoplectus fluviatilis* |
| MISC | *Mikania scandens* |
| PIPU | *Pilea pumila* |
| PHAU | *Phragmites australis* |
| CASE | *Calystegia sepium* |
| APAM | *Apios americana* |
| BOCY | *Boehmeria cylindrica* |
| EUPSP | *Eupatorium species* |
| CIMA | *Cicuta maculata* |
| FRPE | *Fraxinus pennsylvanica* |
| MEAR | *Mentha arvensis* |
| Cyperacene | *Cyperacene* species |
| LEVI | *Lepidium virginicum* |
| CUGR | *Cuscuta gronovii* |
| DEAD | Dead material |
| WATER | Water present |
| BARE | Exposed soil |
| PERL | Exposed perlite |
| POSA | *Polygonum sagittatum* |
| ASSP | *Asclepias speciosa* |
| POAP | *Polypodium appalachianum* |
| SPEU | *Sparganium eurycarpum* |
| Aster Sp | *Aster* species |
| Sparganium | *Sparganium* species |

**Table D2. Raw vegetation data from each plot at the *Phragmites*-dominant site on 5/25/04.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 6.57 | 4.41 | 4.61 | 4.79 | 3.79 | 4.85 | 5.37 | 4.04 |
| SEL | 0.03 | 0.12 | 0.04 | 0.02 | 0.16 | 0.14 | 0.18 | 0.24 |
| Notes: | 11:25, sun | sun | sun | 13:03, sun* ahead tilley | 13:10, sun* ahead tilley | 13:42, sun* ahead tilley | 13:19, sun* ahead tilley | 13:34, sun, |
| TYSP | | 2 | 2 | | 3 | 2 | 3 | 3 |
| PEVI | 8 | 7 | 8 | 7 | 8 | 7 | 8 | 9 |
| HIMO | 5 | | | | | | | |
| POAR | 7 | 6 | 7 | 7 | 6 | 6 | 7 | 6 |
| IMCA | 5 | | 2 | 6 | 2 | 6 | 1 | 0 |
| BILA | | 7 | 2 | 4 | 3 | 2 | 3 | 2 |
| SISU | 1 | 3 | 5 | | | 5 | 1 | |
| CIAR | | | | | | 2 | 1 | |
| LEOR | 7 | 2 | | | | | | |
| ZIAQ | | 2 | | | | | | |
| AMCA | | | 2 | 2 | 3 | | 4 | 2 |
| BTS5B | 2 | | | | | | | |
| SALA | 2 | | | | | | | 2 |
| LIAR | | | 5 | | | | | |
| ELOB | | | 5 | | | | | |
| SCTA | | | 1 | 5 | 2 | | | |
| NULU | | | | | | | 6 | |
| ACCA | | | | | | 1 | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| STPA? | | | | | | | | |
| CASE | | | | | | | | |
| MEAR | | | | | | | | |
| Cyperacene | | | | | | | | |
| LEVI | | | | | | | | |
| CUGR | | | | | | | | |
| DEAD | 2 | 3 | 1 | 2 | 3 | 5 | 2 | 2 |
| WATER | 1 | 4 | 4 | 1 | 1 | 0 | 2 | 2 |
| BARE | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 3 |
| PERL | | | | | | | | |
| Species Richness | 8 | 7 | 10 | 6 | 7 | 8 | 9 | 7 |
| NH3 (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA |
| RP (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA |

**Table D2 continued.**

| plot # | 7m102 | 6m222 | 5m111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|
| LAI | 4.6 | 7.73 | 6.3 | 6.43 | 5.58 | 5.97 | 5.8 |
| SEL | 0.45 | 0.05 | 0.1 | 0.02 | 0.17 | 0.02 | 0.05 |
| Notes: | 16.31 haze | 16.48 haze, whorled leaves | | 17.24 haze | 17.40 haze | 17.55 sun | 18.10 sun |
| TYSP | | | | | | 5 | 2 |
| PEVI | 7 | | 7 | | | 7 | 7 |
| HIMO | | | | | | | 4 |
| POAR | 2 | 7 | 7 | 6 | 7 | | 6 |
| IMCA | | 6 | 3 | 5 | | 7 | 5 |
| BILA | 1 | | 2 | | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | | 3 | | 2 | | |
| BTS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 6 | 6 | | 4 | | 6 | 7 |
| SCFL | 3 | 2 | | 2 | | | |
| MISC | | | 6 | 2 | | | |
| PIPU | 2 | | | 2 | 2 | | |
| PHAU | 7 | 6 | 8 | 8 | 7 | 7 | 6 |
| STPA? | 2 | | | | | | |
| CASE | | | | 6 | 7 | | |
| APAM | | 2 | 4 | | | | |
| BOCY | 5 | 5 | 2 | | 5 | | |
| EUPSP | | 5 | | | | | |
| CIMA | | | 6 | | | | |
| FRPE | | | 2 | | | | |
| MEAR | | | | | 6 | 6 | |
| Cyperacene | | | | | | | |
| LEVI | | | 33/34 | | | | |
| CUGR | | | | | 1 | | |
| DEAD | 3 | 2 | 6 | 7 | 6 | 2 | 3 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| BARE | 5 | | 2 | 3 | 3 | 3 | 3 |
| PERL | | 2 | | | | | |
| Species Richness | 9 | 8 | 11 | 8 | 8 | 6 | 7 |
| NH3 (mg/L) | NA | NA | NA | NA | NA | NA | NA |
| RP (mg/L) | NA | NA | NA | NA | NA | NA | NA |

**Table D3. Raw vegetation data from each plot at the *Phragmites*-absent site on 5/25/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 6.55 | 6.24 | 6.82 | 5.87 | 5.02 | 5.59 | 4.22 |
| SEL | 0.13 | 0.29 | 0.83 | 0.06 | 0.98 | 0.03 | 0.36 |
| Notes: | partly cloudy | photo of a.b. | | moved sm. post | sun | sun | sun |
| TYSP | 3 | 5 | 4 | 4 | 4 | 3 | 3 |
| PEVI | 8 | 9 | 8 | 9 | 8 | 7 | 7 |
| HIMO | 4 | | | | 7 | | 3 |
| POAR | 8 | 7 | 5 | 7 | 6 | 5 | 5 |
| IMCA | 4 | 4 | 8 | 6 | 6 | 7 | 8 |
| BILA | 3 | 4 | 2 | 3 | 3 | 5 | 5 |
| SISU | | | 2 | | | 2 | 2 |
| CIAR | | | 3 | 2 | | | |
| LEOR | | | | 3 | 2 | 4 | |
| ZIAQ | | | | | | | 3 |
| AMCA | | 2 | | | | | 2 |
| BTS5B | | | | | | | |
| SALA | | | | | 2 | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 1 | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| Cyperacene | | | | | | | |
| LEVI | | | | | | | |
| CUGR | | | | | | | |
| DEAD | 2 | 2 | 2 | 4 | 6 | 7 | 5 |
| WATER | 4 | 3 | 2 | 2 | 2 | 3 | 1 |
| BARE | 0 | 0 | 0 | 0 | 5 | 0 | 4 |
| PERL | | | | | | | |
| Species Richness | 7 | 6 | 7 | 7 | 8 | 7 | 9 |
| NH3 (mg/L) | NA | NA | NA | NA | NA | NA | NA |
| RP (mg/L) | NA | NA | NA | NA | NA | NA | NA |

**Table D3 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 6.57 | 4.41 | 4.61 | 4.79 | 3.79 | 4.85 | 5.37 | 4.04 |
| SEL | 0.03 | 0.12 | 0.04 | 0.02 | 0.16 | 0.14 | 0.18 | 0.24 |
| Notes: | 11:25, sun | sun | sun | 13:03, sun* ahead tilley | 13:10, sun* ahead tilley | 13:42, sun* ahead tilley | 13:19, sun* ahead tilley | 13:34, sun, |
| TYSP | | 2 | 2 | | 3 | 2 | 3 | 3 |
| PEVI | 8 | 7 | 8 | 7 | 8 | 7 | 8 | 9 |
| HIMO | 5 | | | | | | | |
| POAR | 7 | 6 | 7 | 7 | 6 | 6 | 7 | 6 |
| IMCA | 5 | | 2 | 6 | 2 | 6 | 1 | 0 |
| BILA | | 7 | 2 | 4 | 3 | 2 | 3 | 2 |
| SISU | 1 | 3 | 5 | | | 5 | 1 | |
| CIAR | | | | | | 2 | 1 | |
| LEOR | 7 | 2 | | | | | | |
| ZIAQ | | 2 | | | | | | |
| AMCA | | | 2 | 2 | 3 | | 4 | 2 |
| BTS5B | 2 | | | | | | | |
| SALA | 2 | | | | | | | 2 |
| LIAR | | | 5 | | | | | |
| ELOB | | | 5 | | | | | |
| SCTA | | | 1 | 5 | 2 | | | |
| NULU | | | | | | | 6 | |
| ACCA | | | | | | 1 | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| STPA? | | | | | | | | |
| CASE | | | | | | | | |
| APAM | | | | | | | | |
| BOCY | | | | | | | | |
| EUPSP | | | | | | | | |
| CIMA | | | | | | | | |
| FRPE | | | | | | | | |
| MEAR | | | | | | | | |
| Cyperacene | | | | | | | | |
| LEVI | | | | | | | | |
| CUGR | | | | | | | | |
| DEAD | 2 | 3 | 1 | 2 | 3 | 5 | 2 | 2 |
| WATER | 1 | 4 | 4 | 1 | 1 | 0 | 2 | 2 |
| BARE | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 3 |
| PERL | | | | | | | | |
| Species Richness | 8 | 7 | 10 | 6 | 7 | 8 | 9 | 7 |
| NH3 (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA |
| RP (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA |

**Table D4. Raw vegetation data from each plot at the *Phragmites*-dominant site on 6/03/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 3.96 | 4.02 | 5.7 | 4.67 | 4.35 | 4.99 | 4.45 |
| SEL | 0.23 | 0.45 | 0.36 | 0.69 | 0.2 | 0.22 | 0.26 |
| Notes: | 11:00, sun | 11:18, sun | 11:35 sun | 11:44 sun | 11:53 sun & wind | 12:03 full sun and wind | 12:12 sun |
| TYSP | | | 4 | | | | |
| PEVI | 3 | 8 | 4 | 3 | 3 | 2 | 5 |
| HIMO | | | 4 | | | | |
| POAR | 4 | 3 | 5 | 4 | 4 | 5 | 3 |
| IMCA | 4 | 3 | 4 | 3 | 7 | 5 | 5 |
| BILA | | | | 1 | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 1 | | 1 | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 5 | 6 | 6 | 5 | 5 | 5 | 4 |
| SCFL | 4 | 1 | | | | | |
| MISC | 5 | 2 | 2 | 3 | | 0 | |
| PIPU | | | | 1 | | | 1 |
| PHAU | 8 | 9 | 7 | 9 | 9 | 8 | 9 |
| CASE | | | | | | 4 | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| Cyperacene | | | | | | | |
| LEVI | | | | | | | |
| CUGR | | | | | | | |
| DEAD | 3 | 3 | 2 | 4 | 4 | 3 | 3 |
| WATER | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| BARE | 3 | 2 | 3 | 3 | 4 | 4 | 3 |
| PERL | | 2 | 3 | 3 | 5 | 4 | 4 |
| Species Richness | 7 | 8 | 8 | 9 | 5 | 7 | 6 |
| NH3 (mg/L) | 0.3 | 5.2 | NA | 7.8 | 2.3 | 1.7 | 2.4 |
| RP (mg/L) | 0.13 | 0.12 | NA | 0.02 | 0.01 | 0.02 | 0.08 |

**Table D4 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 5.73 | 3.41 | 4.69 | 3.23 | 4.6 | 4.85 | 4.75 | 5.62 |
| SEL | 0.38 | 0.26 | 0.12 | 1.11 | 0.51 | 0.02 | 0.12 | 0.42 |
| Notes: | 12:27:00 sun PM | 12:32 sun | 12.42 SUN | 12.56 SUN | 13.05 Some clouds, sun | 13.14 sun | 13.19 Cloudy | 13.30 Sun |
| TYSP | | | | | | | 5 | 3 |
| PEVI | 2 | 6 | 4 | 4 | | | 7 | 6 |
| HIMO | 3 | | | | | | | 3 |
| POAR | 2 | 3 | 5 | 3 | 2 | 5 | 4 | 4 |
| IMCA | 5 | | 5 | 1 | 4 | 3 | 6 | 5 |
| BILA | | 0 | | 0 | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | 0 | | 1 | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 2 | 6 | 4 | 4 | 3 | | 5 | 7 |
| SCFL | | 0 | 3 | | 1 | | | |
| MISC | | | | 0 | 0 | | | |
| PIPU | | 0 | | | 1 | 1 | | |
| PHAU | 9 | 7 | 6 | 8 | 7 | 7 | 7 | 7 |
| CASE | | | | 4 | 6 | 7 | | |
| APAM | 5 | | 0 | 1 | | | | |
| BOCY | | 1 | 2 | 1 | | 1 | | |
| EUPSP | | | 4 | | | | | |
| CIMA | | | | 1 | | | | |
| FRPE | | | | 0 | | | | |
| MEAR | | | | | | 0 | 1 | |
| Cyperacene | | | | | | | | |
| LEVI | | | | | | | | |
| CUGR | | | | | | 0 | | |
| DEAD | 2 | 5 | 2 | 2 | 3 | 3 | 3 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| BARE | 2 | 5 | 1 | 4 | 1 | 1 | 1 | 4 |
| PERL | 1 | 3 | 0 | 1 | 2 | 3 | 1 | 1 |
| Species Richness | 7 | 8 | 9 | 13 | 8 | 9 | 7 | 7 |
| NH3 (mg/L) | 1.8 | 1.7 | 3.1 | 3.3 | 2 | 3.7 | NA | 6.7 |
| RP (mg/L) | 0.01 | 0.12 | 0.91 | NA | 0.01 | 0.35 | NA | 0.05 |

**Table D5. Raw vegetation data from each plot at the *Phragmites*-absent site on 6/03/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| **LAI** | 3.62 | 3.71 | 3.41 | 4.86 | 5.19 | 4.07 | 4.14 |
| **SEL** | 0.06 | 1.19 | 0.03 | 0.56 | 0.48 | 0.68 | 1.01 |
| **Notes:** | 14.22 Sun | 14.29 Sun | 14.37 Sun | 14.52 Some clouds, Sun for LAI | 14.59 Sun | 15.19 Sun | 14.45 Sun, partly cloudy |
| **TYSP** | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| **PEVI** | 8 | 7 | 8 | 8 | 8 | 6 | 7 |
| **HIMO** | 4 | | 3 | | 6 | | 0 |
| **POAR** | 5 | 8 | 4 | 3 | 5 | 3 | 5 |
| **IMCA** | 4 | 2 | 6 | 5 | 3 | 6 | 7 |
| **BILA** | 1 | 1 | 2 | 0 | | 3 | 2 |
| **SISU** | | | | 1 | | | 0 |
| **CIAR** | | | 2 | 4 | | | |
| **LEOR** | | | | 0 | | 4 | |
| **ZIAQ** | | | | | | | 0 |
| **AMCA** | | 1 | | | | | |
| **SALA** | | | | | | | |
| **LIAR** | | | | | | | |
| **ELOB** | | | | | | | |
| **SCTA** | | | | | | | |
| **NULU** | | | | | | | |
| **ACCA** | 0 | | | | 1 | | |
| **SCFL** | | | | | | | |
| **MISC** | | | | | | | |
| **PIPU** | | | | | | | |
| **PHAU** | | | | | | | |
| **CASE** | | | | | | | |
| **APAM** | | | | | | | |
| **BOCY** | | | | | | | |
| **EUPSP** | | | | | | | |
| **CIMA** | | | | | | | |
| **FRPE** | | | | | | | |
| **MEAR** | | | | | | | |
| **Cyperacene** | | | | | | | |
| **LEVI** | | | | | | | |
| **CUGR** | | | | | | | |
| **DEAD** | 1 | 2 | 3 | 4 | 3 | 4 | 3 |
| **WATER** | 1 | 1 | 1 | 3 | 1 | 1 | 2 |
| **BARE** | 1 | 2 | 1 | 1 | 2 | 2 | 2 |
| **PERL** | 2 | 2 | 3 | 4 | 1 | 2 | 3 |
| **Species Richness** | 7 | 6 | 7 | 8 | 6 | 6 | 8 |
| **NH3 (mg/L)** | NA | NA | 0.3 | 0.1 | 0.8 | NA | NA |
| **RP (mg/L)** | NA | NA | 0.11 | 0.13 | 0.05 | NA | NA |

**Table D5 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| **LAI** | 5.63 | 5.37 | | 3.28 | 3.72 | 3.18 | 2.27/2.99 | 2.4 |
| **SEL** | 1.75 | 0.02 | | 0.47 | 0.5 | 0.35 | 0.63/0.89 | 0.08 |
| **Notes:** | 15.08 Sun | 15.28 Sun | | 15.34 Cloudy with sun | 15.40 Partly cloudy | 16.01 Sun | 15.48 Sun | 15.55 Partly cloudy |
| **TYSP** | | 3 | | 2 | 2 | 4 | 4 | 4 |
| **PEVI** | 6 | 9 | | 6 | 8 | 7 | 8 | 9 |
| **HIMO** | 3 | | | 4 | | | | |
| **POAR** | 3 | 3 | | 6 | 6 | 5 | 7 | 4 |
| **IMCA** | 3 | 4 | | 6 | 0 | 6 | | |
| **BILA** | 1 | 1 | | 4 | 3 | 3 | 2 | 2 |
| **SISU** | | 0 | | | | 1 | | |
| **CIAR** | | | | | | 3 | 1 | |
| **LEOR** | 5 | 3 | | | | | | |
| **ZIAQ** | | | | | | | | |
| **AMCA** | | | | 0 | 0 | | | |
| **SALA** | | | | | | | | |
| **LIAR** | | | | | | | | |
| **ELOB** | | | | | | | | |
| **SCTA** | | | | 5 | 2 | | | |
| **NULU** | | | | | | | 5 | |
| **ACCA** | | | | | | | | |
| **SCFL** | | | | | | | | |
| **MISC** | | | | | | | | |
| **PIPU** | | | | | | | | |
| **PHAU** | | | | | | | | |
| **CASE** | | | | | | | | |
| **APAM** | | | | | | | | |
| **BOCY** | | | | | | | | |
| **EUPSP** | | | | | | | | |
| **CIMA** | | | | | | | | |
| **FRPE** | | | | | | | | |
| **MEAR** | | | | | | | | |
| **Cyperacene** | | | | | | | | |
| **LEVI** | | | | | | | | |
| **CUGR** | | | | | | | | |
| **DEAD** | 2 | 2 | | 1 | 2 | 2 | 2 | 2 |
| **WATER** | 1 | 3 | | 2 | 3 | 2 | 2 | 4 |
| **BARE** | 3 | 1 | | 3 | 3 | 2 | 2 | 2 |
| **PERL** | 3 | 1 | | 3 | 3 | 3 | 2 | 2 |
| **Species Richness** | 6 | 7 | | 8 | 7 | 7 | 6 | 4 |
| **NH3 (mg/L)** | 0.5 | 0.4 | | NA | NA | NA | 0 | 0.1 |
| **RP (mg/L)** | 0.02 | 0.08 | | NA | NA | NA | 0.13 | 0.03 |

**Table D6. Raw vegetation data from each plot at the *Phragmites*-dominant site on 6/16/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 5.56 | 4.2 | 5.93 | 4.92 | 4.55 | 6.68 | 5.33 |
| SEL | 0.06 | 0.02 | 0.26 | 0.37 | 0.16 | 0.11 | 0.04 |
| Notes: | 9.10, Cl, LAI away from water | 9.43, cl., LAI - inland | 10.03, cl. LAI - inland | 10.19, cl. LAI - inland | 10.34, cl. LAI - inland | 10.45, cl. LAI - inland | 10.58, cl. LAI - inland |
| TYSP | 2 | | | | | | |
| PEVI | 2 | 7 | 5 | | 3 | 4 | 6 |
| HIMO | | | 6 | 1 | | | |
| POAR | 7 | 6 | 7 | 8 | 6 | 6 | 5 |
| IMCA | 5 | 5 | 6 | 7 | 8 | 7 | 6 |
| BILA | | | | 2 | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 1 | | | | 1 | |
| BTS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 7 | 7 | 7 | 6 | 6 | 7 | 6 |
| SCFL | 5 | 4 | | | | | |
| MISC | 4 | 4 | | 4 | | 4 | |
| PIPU | | 1 | | 2 | | 1 | 4 |
| PHAU | 8 | 8 | 8 | 8 | 9 | 8 | 8 |
| STPA? | 3 | | | | | | |
| CASE | | | | | | 4 | |
| APAM | | | | | | | |
| LEVI | | | | | | | |
| BISPC | | | | 1 | | | |
| POSA | | | | | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| CUGR | | 2 | | | | | 1 |
| DEAD | 5 | 6 | 6 | 7 | 6 | 6 | 7 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 2 | 3 | 2 | 3 | 3 | 2 | 4 |
| PERL | 2 | 3 | 3 | 2 | 3 | 1 | 3 |
| Richness | 9 | 10 | 6 | 9 | 5 | 9 | 7 |
| NH3 (mg/L) | 0.38 | 2.66 | 25.3 | 14.9 | 0.8 | 1.8 | 1.04 |
| Total Nitrate | 1.4 | 2 | 1.6 | 3.2 | 1.4 | 2.7 | 1.5 |
| Total N | 15 | 11.25 | 26.25 | 18.75 | 11.25 | 11.25 | 11.25 |
| TP (mg/L) | 0.06 | 2.5 | 0.31 | 0.22 | 0.77 | 0.22 | 0.7 |

**Table D6 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 7.54 | 4.71 | 5.57 | 4.83 | 5.3 | 6.82 | 5.81 | 6.22 |
| SEL | 0.39 | 0.38 | 0.04 | 0.37 | 0 | 0.06 | 0.8 | 0.11 |
| Notes: | 11.10, cl, LAI - inland | 11.24, cl. LAI - water | 11.34, cl. LAI - water | 11.48, cl, LAI - water | 12.01, p.cl | 12.12, p.sunny | 12.26, p. sunny | 12.37, p. sunny |
| TYSP | | | | | | | 6 | |
| PEVI | | 5 | 6 | | | | 6 | 5 |
| HIMO | 5 | | | | | | | 6 |
| POAR | 5 | 5 | 7 | 6 | 6 | 9 | 6 | 6 |
| IMCA | 6 | | 7 | 4 | 7 | 5 | 7 | 6 |
| BILA | | | | 2 | | 2 | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 5 | 6 | 7 | 4 | 5 | | 6 | 8 |
| SCFL | | 4 | | | | 4 | | |
| MISC | | | 4 | | | | | |
| PIPU | | | | 1 | 3 | | | |
| PHAU | 9 | 7 | 6 | 8 | 8 | 8 | 7 | 6 |
| STPA? | 9 | | | | | | | |
| CASE | | | | 6 | 6 | 6 | | |
| APAM | 4 | | | 5 | | | | |
| BOCY | | 5 | 4 | 3 | | 5 | | |
| EUPSP | | | 5 | | | | | |
| CIMA | | | | 5 | | | | |
| MEAR | | | | | | 5 | 5 | |
| BISPC | | | | 4 | | | | |
| POSA | | | 3 | | | | | |
| ASSP | | | | | | 3 | | |
| STPA2 | | 4 | | | | | | |
| CUGR | | | | | 2 | 4 | | |
| DEAD | 7 | 5 | 3 | 6 | 6 | 6 | 6 | 5 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 1 | 5 | 4 | 4 | 4 | 2 | 4 | 4 |
| PERL | 1 | 3 | 0 | 4 | 3 | 2 | 0 | 2 |
| Richness | 7 | 7 | 9 | 11 | 7 | 10 | 7 | 6 |
| NH3 (mg/L) | 3.06 | 1.06 | 16.3 | 2.44 | 1.12 | 1.9 | 6.6 | 90.8 |
| Nitrate (mg/L) | 1.7 | 1.2 | 3.2 | 1.8 | 2 | 3.2 | 2 | 1.1 |
| Total N | 11.25 | 7.5 | 26.25 | 3.75 | 15 | 15 | 3.75 | 97.5 |
| TP (mg/L) | 0.68 | 0.05 | 5 | 0.24 | 2.7 | 0.13 | 6.4 | 0.28 |

**Table D7. Raw vegetation data from each plot at the *Phragmites*-absent site on 6/16/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 3.75 | 5.83 | 4.81 | 5.81 | 6.43 | 5.01 | 6.32 |
| SEL | 0.1 | 0.57 | 0.65 | 0.16 | 0.14 | 0.19 | 0.2 |
| Notes: | 13.27, cl, lai - - dstream | 13.35, p. cloudy | 13.45, p. sunny | 13.55, p. sunny | 15.18, p.sunny | 15.11, p.sunny | 14.04, cl, lai - dstr. |
| TYSP | 3 | 6 | 5 | 4 | 5 | 6 | 5 |
| PEVI | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| HIMO | 5 | | | | 6 | | 4 |
| POAR | 8 | 9 | 6 | 8 | 9 | 5 | 7 |
| IMCA | 6 | 5 | 7 | 7 | 6 | 9 | 9 |
| BILA | | 5 | 3 | 4 | 1 | 1 | 4 |
| SISU | | | | | | 4 | |
| CIAR | | 2 | 4 | 3 | | | |
| LEOR | | | | 5 | 5 | 6 | |
| ZIAQ | | | | | | | 4 |
| AMCA | 3 | 1 | | | | | |
| BTS5B | | | | | | | |
| SALA | | | | | 6 | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| LEVI | | | | | | | |
| BISPC | | | | | | | |
| POSA | | | | | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| CUGR | | | | 3 | | | |
| DEAD | 4 | 4 | 2 | 3 | 4 | 2 | 4 |
| WATER | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| BARE | 4 | 2 | 2 | 4 | 3 | 4 | 4 |
| PERL | 4 | 4 | 3 | 4 | 2 | 4 | 4 |
| Richness | 6 | 7 | 6 | 8 | 8 | 7 | 7 |
| NH3 (mg/L) | 0.42 | 31.6 | 0.54 | 1 | | 1.6 | 3.3 |
| Nitrate (mg/L) | 1.5 | | 1.4 | 0.8 | | 0 | 1.4 |
| Total N | 11.25 | 37.5 | 11.25 | 7.5 | | 11.25 | 11.25 |
| TP (mg/L) | 0.2 | 2.6 | 0.15 | 0.24 | | 0.29 | 0.62 |

**Table D7 continued**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 5.52 | 6.48 | 4.97 | 6.62 | 4.71 | 5.93 | 6.57 | 3.51 |
| SEL | 0.32 | 0.27 | 0.66 | 0.04 | 0.19 | 0.3 | 0.23 | 0.08 |
| Notes: | 15.05, p.cl.lai - dstr. | 14.13, p. sun, lai - upstream | 14.56, p.cl. | 14.20, p. sun. lai - upstr. | 14.28, p.sun, lai- upstr. | 14.49, cl. Lai - upstr. | 14.34, cl. Lai - upstr. | 14.41, cl, lai - upstream |
| TYSP | 1 | 4 | 2 | 2 | 4 | 5 | 4 | 5 |
| PEVI | 6 | 7 | 7 | 7 | 8 | 7 | 7 | 8 |
| HIMO | 6 | | | | | | | |
| POAR | 9 | 8 | 7 | 8 | 8 | 8 | 9 | 7 |
| IMCA | 7 | 6 | 4 | 8 | 4 | 8 | 6 | |
| BILA | | 6 | 4 | 4 | 5 | 2 | 2 | |
| SISU | 2 | 3 | 5 | 3 | | 5 | | |
| CIAR | | | 6 | | | 5 | | |
| LEOR | 7 | | 5 | 1 | | | | 1 |
| ZIAQ | | 4 | | | | | | |
| AMCA | | | | | | | 2 | 4 |
| BTS5B | 3 | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | 6 | | | | | |
| SCTA | | | 2 | 6 | 2 | | | |
| NULU | | | | | | | 6 | |
| ACCA | | | | | | 2 | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| LEVI | | | | | | | | |
| BISPC | | | | | | | | |
| POSA | | | | | | | | |
| ASSP | | | | | | | | |
| STPA2 | | | | | | | | |
| CUGR | | | | | | | | |
| DEAD | 3 | 3 | 2 | 0 | 3 | 4 | 3 | 4 |
| Water | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| BARE | 4 | 3 | 4 | 2 | 4 | 4 | 4 | 5 |
| PERL | 4 | 4 | 2 | 3 | 4 | 5 | 4 | 0 |
| Richness | 8 | 7 | 10 | 8 | 6 | 8 | 7 | 5 |
| $NH_3$ (mg-N/L) | 0.92 | 4.34 | 1.62 | 37 | 0.82 | 3.4 | 0.64 | 0.42 |
| Nitrate (mg/L) | 0.9 | 0.9 | 1.5 | 1.3 | 2.3 | 3.9 | 1.7 | 2.1 |
| Total N | 11.25 | 11.25 | 15 | 15 | 18.75 | 11.25 | 11.25 | 11.25 |
| TP (mg-P/L) | 0.67 | 4.5 | 1.2 | 0.47 | 0.48 | 0.18 | 1.8 | 2.7 |

**Table D8. Raw vegetation data from each plot at the Phragmites-dominant site on 6/29/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 4.42 | 2.98 | 6.54 | 4.48 | 4.8 | 4.86 | 5.01 |
| SEL | 0.33 | 0.04 | 0.7 | 0.31 | 0.07 | 0.06 | 0.05 |
| Notes: | 3:25, full sun | 3:27, full sun | 3:29, full sun | 3:32, full sun | 3:33, full sun | 3:35, full sun | 3:39, full sun |
| TYSP | | | 5 | | | | |
| PEVI | 1 | 6 | | 5 | 1 | 2 | 5 |
| HIMO | | | 6 | | | | |
| POAR | 6 | 5 | 8 | 6 | 4 | 7 | 4 |
| IMCA | 7 | 6 | 6 | 7 | 7 | 7 | 7 |
| BILA | | | | 1 | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 3 | | | | | 4 |
| BTS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 5 | 4 | 6 | 6 | 5 | 4 | 6 |
| SCFL | 4 | 4 | | | | | |
| MISC | 4 | | | | | | |
| PIPU | | | | 4 | | 3 | 3 |
| PHAU | 7 | 9 | 8 | 7 | 8 | 8 | 8 |
| STPA? | | | | | | | |
| CASE | | | | | | 5 | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| STPA2 | | | | | | | |
| unknown1 | | | | | | | |
| CUGR | | | | | | | 2 |
| DEAD | 4 | 5 | 4 | 4 | 4 | 3 | 5 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 1 | 3 | 1 | 2 | 3 | 2 | 3 |
| PERL | 1 | 2 | 0 | 2 | 2 | 2 | 2 |
| Richness | 7 | 7 | 6 | 7 | 5 | 7 | 8 |
| NH3 (mg/L) | 0.4 | 1.06 | 29.6 | | 0.56 | 0.92 | 0.66 |
| Nitrate | 1.6 | | 0.7 | | 1.1 | 2.1 | 1.6 |
| Total N | 11.25 | 3.75 | 26.25 | | 15 | 3.75 | 11.25 |
| TP (mg/L) | 0.06 | 1.7 | 0.16 | | 0.03 | 0.01 | 0.02 |

**Table D8 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 6.86 | 3.38 | 4.72 | 5.18 | 4.36 | 5.29 | 5.25 | 3.31 |
| SEL | 0.08 | 0.48 | 0 | 0.11 | 0 | 0.35 | 0.07 | 0.11 |
| Notes: | 3:37, full sun | 3:41, full sun | 3:44, full sun | 3:46, full sun | 3:47, full sun | 3:49, cloud | 3:51, cloud | 3:52, cloud |
| TYSP | | | | | | | 5 | 4 |
| PEVI | | 6 | 1 | 5 | 3 | | | 3 |
| HIMO | 1 | | 4 | | | | | 5 |
| POAR | 4 | 6 | 7 | 6 | 7 | 8 | 6 | 5 |
| IMCA | 5 | 5 | 6 | 4 | 7 | 7 | 8 | 7 |
| BILA | | | 3 | | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | | | |
| BTS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 5 | 7 | 5 | 5 | 4 | | 4 | 8 |
| SCFL | | 6 | 6 | | | | 4 | |
| MISC | | | | | | | | |
| PIPU | | 2 | | 3 | 3 | | | |
| PHAU | 8 | 7 | 6 | 6 | 7 | 6 | 6 | 6 |
| STPA? | 8 | | | | | | | |
| CASE | | | | 6 | 5 | 5 | | |
| APAM | 4 | | | 4 | | | | |
| BOCY | | 5 | 5 | 2 | | 3 | | |
| EUPSP | | | | | | | | |
| CIMA | | | | 5 | | | | |
| FRPE | | | | | | | | |
| MEAR | | | | | | 5 | 4 | |
| STPA2 | | 3 | | | | | | |
| unknown1 | | | | | | | | |
| CUGR | 3 | | | | 3 | 2 | | |
| DEAD | 4 | 3 | 3 | 4 | 5 | 3 | 4 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 1 | 4 | 3 | 2 | 3 | 2 | 3 | 4 |
| PERL | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| Richness | 8 | 9 | 9 | 10 | 8 | 7 | 7 | 7 |
| NH3 (mg/L) | 1.24 | 1 | 20.5 | 2.18 | | 1.12 | 1.28 | 79.5 |
| Nitrate | 0.9 | 1.2 | 4.4 | 2.9 | 2.2 | | 1.5 | 0.6 |
| Total N | 15 | 3.75 | 22.5 | 11.25 | | 11.25 | 7.5 | 97.5 |
| TP (mg/L) | 0.07 | 0.02 | 0.62 | 0 | | 0.02 | 0.04 | 0.1 |

**Table D9. Raw vegetation data from each plot at the *Phragmites*-absent site on 6/29/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 4.37 | 3.71 | 2.32 | 4.43 | 5.1 | 2.97 | 4.97 |
| SEL | 0 | 0.42 | 0 | 0 | 0.14 | 0 | 0.17 |
| Notes: | 1:05pm | 1:15pm, sun | 1:20pm, sun | 1:31pm, full sun | 1:40pm. Full sun | 1:59pm, full sun | 2:25pm, sun |
| TYSP | 5 | 5 | 5 | 4 | 4 | 5 | 4 |
| PEVI | 6 | 7 | 8 | 8 | 5 | 6 | 5 |
| HIMO | 6 | | | | 7 | | 1 |
| POAR | 8 | 9 | 6 | 8 | 8 | 4 | 5 |
| IMCA | 5 | 5 | 8 | 8 | 4 | 9 | 9 |
| BILA | 3 | 4 | | 1 | | 1 | 3 |
| SISU | | | | | | 4 | |
| CIAR | | 1 | 5 | 3 | | | |
| LEOR | | | | 4 | 5 | 4 | |
| ZIAQ | | | | | 1 | | 4 |
| AMCA | 5 | 3 | | | | | |
| BTS5B | | | | | | | |
| SALA | | | | | 5 | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| LEVI | | | | | | | |
| BISPC | | | | | | | |
| POSA | | | | | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| unknown1 | | | | | | | |
| CUGR | | | | 4 | | | |
| DEAD | 2 | 4 | 1 | 1 | 2 | 1 | 3 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 3 | 4 | 3 | 2 | 1 | 2 | 3 |
| PERL | 1 | 3 | 0 | 0 | 1 | 2 | 0 |
| Richness | 7 | 7 | 5 | 8 | 8 | 7 | 7 |
| NH3 (mg/L) | 0.5 | 44.4 | 0.62 | 1.16 | 1.12 | 1.1 | 3.12 |
| Total Nitrate | 0.9 | | 2.2 | 0 | 0.2 | 1.8 | 0.8 |
| Total N | 11.25 | 15 | 3.75 | 7.5 | 11.25 | 11.25 | 11.25 |
| TP (mg/L) | 0.09 | | 0.17 | 0.21 | 0.15 | 0.27 | 0.42 |

**Table D9 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 3.55 | 4.41 | 1.94 | 4.99 | 3.94 | 4.25 | 4.78 | 3.11 |
| SEL | 0.65 | 0.18 | 0.42 | 0.16 | 1.14 | 0.08 | 0.05 | 0.18 |
| Notes: | 1:50pm, full sun | 2:05pm, small cloud | 3:05, full sun | 2:10pm, sun | 2:30pm, sun | 2:56pm, full sun | 2:40pm, sun | 2:50pm, full sun |
| TYSP | | 5 | 4 | 4 | 4 | 4 | 4 | 4 |
| PEVI | 5 | 6 | 6 | 6 | 7 | 6 | 8 | 8 |
| HIMO | 5 | | | | | | | |
| POAR | 7 | 8 | 6 | 8 | 8 | 7 | 8 | 7 |
| IMCA | 4 | 6 | 4 | 8 | 3 | 7 | 5 | |
| BILA | | 5 | 2 | | 4 | 2 | 2 | |
| SISU | 5 | 5 | 5 | 4 | | 6 | | |
| CIAR | | | 6 | | | 4 | | |
| LEOR | 6 | | 4 | | | | | |
| ZIAQ | | 6 | | 3 | | 2 | | 4 |
| AMCA | | | | 2 | 2 | | 2 | 4 |
| BTS5B | 2 | | | | | | | |
| SALA | | | | 2 | | | | 6 |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | 4 | 3 | | | |
| NULU | | | | | | | 7 | |
| ACCA | | | 5 | | | | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| LEVI | | | | | | | | |
| BISPC | | | | | | | | |
| POSA | | | | | | | | |
| ASSP | | | | | | | | |
| STPA2 | | | | | | | | |
| unknown1 | | | | | 2 | | | |
| CUGR | | | | | | | | |
| DEAD | 3 | 3 | 2 | 1 | 1 | 1 | 3 | 2 |
| WATER | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 4 |
| BARE | 5 | 4 | 5 | 3 | 2 | 3 | 3 | 3 |
| PERL | 3 | 0 | 3 | 2 | 0 | 3 | 3 | 1 |
| Richness | 7 | 7 | 9 | 9 | 8 | 8 | 7 | 6 |
| NH3 (mg/L) | 0.66 | 2.1 | 0.88 | 5.2 | 0.68 | 1.4 | 0.9 | 0.34 |
| Total Nitrate | 1.2 | 0.9 | 2.3 | 0.9 | 1.8 | 1.6 | 1.7 | 1.1 |
| Total N | 7.5 | 11.25 | 11.25 | 7.5 | 3.75 | 11.25 | 11.25 | 11.25 |
| TP (mg/L) | 0.15 | 0.31 | 0.22 | 0.2 | 0.34 | 0.15 | 0.21 | 0.19 |

**Table D10. Raw vegetation from each plot at the Phragmites-dominant site on 7/19/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 6.16 | 4.79 | 6.19 | 6.2 | 6.45 | 5.64 | 5.8 |
| SEL | 0.1 | 0.05 | 0.07 | 0.19 | 0.21 | 0.22 | 0.27 |
| Notes: | 10:50, cloudy | 11:20, p. sunny | 11, sunny | 11:30, p. sunny | 11:50, p. sunny | 11:40, p. sunny | 11:55, p.sunny |
| TYSP | 2 | | 2 | | | | |
| PEVI | 1 | 5 | 2 | 2 | | 1 | 4 |
| HIMO | | | | | | | |
| POAR | 8 | 6 | 8 | 7 | 6 | 5 | 4 |
| IMCA | 8 | 3 | 7 | 8 | 8 | 8 | 7 |
| BILA | | | | | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 3 | | | | | 3 |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 2 | 4 | 4 | 5 | 6 | 5 | 5 |
| SCFL | 4 | 4 | | | | | |
| MISC | 2 | 1 | 3 | 1 | | 4 | |
| PIPU | | | | | | | |
| PHAU | 7 | 9 | 6 | 7 | 7 | 6 | 7 |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | 2 | | | 4 | | 2 | 1 |
| EUPSP | | | | | | | |
| MEAR | | | | | | | |
| POAP | | | | | | | |
| unknown6 | | | | | | | 2 |
| CUGR | | 4 | | | | | |
| DEAD | 5 | 5 | 1 | 4 | 4 | 4 | 3 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 1 | 4 | 3 | 2 | 1 | 3 | 3 |
| PERL | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| Species Richness | 9 | 9 | 7 | 7 | 4 | 7 | 8 |
| NH3 (mg/L) | 0.96 | 1.28 | 22.2 | 5.5 | 0.88 | 1.3 | 0.6 |
| Total Nitrate | 1.5 | 1.7 | 1.2 | 8.2 | 0.9 | 2.3 | 1.6 |
| Total N | 6 | 6 | 21 | 7.5 | 4.5 | 6 | 4.5 |
| TP (mg/L) | 0.05 | 0.32 | 0.29 | 0.43 | 0.06 | 0.03 | 0.03 |

**Table D10 continued**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 7.87 | 3.38 | 6.03 | 6.02 | 4.89 | 5.59 | 5.53 | 3.96 |
| SEL | 0.2 | 0.09 | 0.09 | 0.87 | 0.27 | 0.44 | 0.23 | 0.17 |
| Notes: | 12:05, sunny | 12:14, sunny | 12:23, p. sunny | 12:32, sunny | 12:51, p. sunny | 12:42, p. sunny | 1:03, sun | 1:12, p. sunny |
| TYSP | | 3 | | | | | 3 | 5 |
| PEVI | | 5 | 3 | 3 | 3 | | 3 | 2 |
| HIMO | | 3 | | 3 | | | | 4 |
| POAR | 3 | 6 | 8 | 8 | 7 | 8 | 5 | 7 |
| IMCA | 6 | 4 | 5 | 3 | 6 | 4 | 7 | 7 |
| BILA | | | | | | 5 | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | | | |
| BIS5B | | | | 4 | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 3 | 7 | 3 | 3 | 5 | | 4 | 7 |
| SCFL | | 1 | 4 | | | 2 | 7 | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | 8 | 6 | 4 | 7 | 7 | 6 | 5 | 5 |
| STPA? | 9 | | | | | | | |
| CASE | | | | 4 | 6 | 5 | | |
| APAM | 5 | | | 5 | | | | |
| BOCY | | | 5 | 3 | 2 | | | |
| EUPSP | | | | | | | | |
| MEAR | | | | | | 3 | | |
| STPA2 | | 4 | | | | | | |
| POAP | | | 2 | | | | | |
| unknown6 | | | | | | | | |
| CUGR | 4 | | | | | 3 | | |
| DEAD | 5 | 3 | 2 | 4 | 3 | 3 | 2 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 2 | 5 | 1 | 5 | 2 | 3 | 4 | 6 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 7 | 9 | 8 | 10 | 7 | 8 | 7 | 7 |
| NH3 (mg/L) | 2.4 | 0.62 | 30 | 1.86 | 1.54 | 1.08 | 0.78 | 75 |
| Total Nitrate | 1.5 | 1.2 | 8.5 | 5 | 4 | 1.9 | 1.7 | 0.6 |
| Total N | 6 | 4.5 | 25.5 | 6 | 7.5 | 4.5 | 3 | 22.5 |
| TP (mg/L) | 0.35 | 0 | 0.41 | 0 | 0.51 | 0.01 | 0.05 | 0.19 |

**Table D11. Raw vegetation data from each plot at the Phragmites-absent site on 7/19/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 | 8d221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 3.49 | 6.95 | 3.9 | 5.07 | 6.71 | 3.31 | 5.52 | 4.05 |
| SEL | 0.67 | 0.21 | 0 | 0.07 | 0.15 | 0.44 | 0.02 | 0.24 |
| Notes: | 14:13, p. sunny | 14:13, p. sunny | 14:24, p. sunny | 15:21, sun | 15:15, p. sunny | 15:28, sunny | 14:29, p. sunny | 15:09, sunny |
| TYSP | 3 | 3 | 4 | 3 | 1 | 3 | 3 | |
| PEVI | 5 | 4 | 6 | 5 | 3 | 5 | 2 | 2 |
| HIMO | 6 | | | | 7 | | 4 | 5 |
| POAR | 8 | 9 | 6 | 7 | 10 | 5 | 6 | 8 |
| IMCA | 4 | 6 | 8 | 7 | 5 | 9 | 9 | 3 |
| BILA | | 2 | | | | 2 | | |
| SISU | | | | | | 4 | | |
| CIAR | | | | 2 | 2 | | | |
| LEOR | | | | 2 | | 3 | | 3 |
| ZIAQ | | | | | 2 | 2 | 2 | |
| AMCA | 4 | 2 | | | | 3 | | |
| BIS5B | | | | | | | | |
| SALA | | | | | 4 | | | 2 |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | | | | | | 1 | | 2 |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| STPA? | | | | | | | | |
| CASE | | | | | | | | |
| APAM | | | | | | | | |
| BOCY | | | | | | | | |
| EUPSP | | | | | | | | |
| CIMA | | | | | | | | |
| POAP | | | | | | | | |
| unknown1 | | | | | | | | |
| unknown6 | | | | | | | | |
| CUGR | | | | 5 | | | | |
| DEAD | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| WATER | 0 | 0 | 2 | 1 | 0 | 0 | 2 | 0 |
| BARE | 4 | 2 | 4 | 3 | 0 | 3 | 1 | 2 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 6 | 6 | 4 | 7 | 8 | 10 | 6 | 7 |
| NH3 (mg/L) | 0.54 | 27.4 | 0.52 | 1.66 | 0.44 | 1.2 | 0.9 | 0.82 |
| Total Nitrate | 1.5 | | 2.2 | 1 | 1.4 | 0.4 | 1.6 | 1.1 |
| Total N | 11.25 | 30 | 11.25 | 11.25 | 0 | 11.25 | 15 | 11.25 |
| TP (mg/L) | 0.04 | 0.35 | 0.45 | 0.25 | 0.06 | 0.31 | 0.36 | 0.08 |

**Table D11 continued.**

| plot # | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|
| LAI | 4.71 | 3.69 | 4.18 | 6.18 | 4.95 | 5.97 | 3.69 |
| SEL | 0.06 | 0.41 | 0.05 | 0.27 | 0.64 | 0.58 | 0.82 |
| Notes: | 15:34, sunny | 15:05, sunny | 15:39, sunny | 14:39, p sunny | 14:55, sun | 14:47, sunny | 14:49, p. sunny |
| TYSP | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| PEVI | 4 | 5 | 5 | 2 | 5 | 2 | 4 |
| HIMO | | | | | | | |
| POAR | 8 | 7 | 8 | 9 | 8 | 9 | 9 |
| IMCA | 7 | 7 | 8 | 2 | 7 | 4 | |
| BILA | 3 | 2 | | 2 | | | |
| SISU | 4 | 4 | | | 7 | | |
| CIAR | | 3 | | | 3 | | |
| LEOR | | | | | | | |
| ZIAQ | 4 | | 3 | | | | 1 |
| AMCA | | | 3 | 2 | 7 | | 3 |
| BIS5B | | | | | | | |
| SALA | | | | | | | 5 |
| LIAR | | | | | | | |
| ELOB | | 2 | | | | | |
| SCTA | | | 3 | | | | |
| NULU | | | | | | 4 | |
| ACCA | | 2 | | | 2 | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | 2 | | | 2 | | |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| MEAR | | | | | | | |
| POAP | | | | | | | |
| unknown1 | | | | | | | |
| unknown6 | | | | | | | |
| CUGR | | 3 | | | | | |
| DEAD | 1 | 2 | 1 | 1 | 1 | 1 | 2 |
| WATER | 1 | 0 | 1 | 0 | 1 | 0 | 3 |
| BARE | 3 | 4 | 2 | 2 | 0 | 0 | 2 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 7 | 11 | 7 | 6 | 9 | 5 | 6 |
| NH3 (mg/L) | 0.94 | 1.16 | 2.8 | 0.82 | 1.3 | 0.5 | 0.54 |
| Total Nitrate | 2.1 | 1.7 | 1.6 | 1.3 | 1.2 | 1.6 | 1.1 |
| Total N | 11.25 | 11.25 | 11.25 | 15 | 11.25 | 7.5 | 7.5 |
| TP (mg/L) | 0.12 | 0.13 | 0.13 | 0.09 | 0.14 | 0.07 | 0.12 |

**Table D12. Raw vegetation data from each plot at the *Phragmites*-dominant site on 8/24/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 6.79 | 4.86 | 6.62 | 7.32 | 5.05 | 4.87 | 4.04 |
| SEL | 0.09 | 0.1 | 0.03 | 0.28 | 0.02 | 0.36 | 0.29 |
| Notes: | 11:06, mostly cloudy | 11:31, mostly cloudy | 11:20 | 11:49 | 11:41 | 11:54, mostly cloudy | 12:02, mostly sunny |
| TYSP | 3 | | | | | | |
| PEVI | | | | 5 | 2 | 2 | 6 |
| HIMO | | | | | | | |
| POAR | 10 | 7 | 8 | 7 | 5 | 5 | 7 |
| IMCA | 4 | 5 | 7 | 8 | 6 | 8 | 7 |
| BILA | | | | | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 2 | | | | | 4 |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | 2 | 2 | | 2 | 3 | 4 |
| SCFL | | 2 | | | | 3 | |
| MISC | | | | | | | |
| PIPU | | | | 3 | | 2 | 3 |
| PHAU | 4 | 8 | 5 | 4 | 8 | 6 | 8 |
| STPA? | | | | | | | |
| CASE | | | | | | 3 | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| POAP | | | | | | | |
| unknown1 | | | | | | | |
| unknown6 | | | | | | | |
| CUGR | | 4 | | 3 | | | |
| DEAD | 3 | 7 | 6 | 5 | 6 | 7 | 7 |
| WATER | 10 | 9 | 4 | 2 | 7 | 1 | 1 |
| BARE | 1 | 4 | 3 | 3 | 5 | 4 | 4 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 4 | 7 | 4 | 6 | 5 | 8 | 7 |
| NH3 (mg/L) | 0.28 | 0.79 | 7.12 | 1.87 | 0.31 | 2.96 | 0.52 |
| Total Nitrate | 1.6 | 1.4 | 1.8 | 2.6 | 1.1 | 2.2 | 1.9 |
| Total N | 11.25 | 15 | 48.75 | 15 | 11.25 | 15 | 15 |
| TP (mg/L) | 0.04 | 0.03 | 0.12 | 0.01 | 0.04 | 0.04 | 0.29 |

**Table D12 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 5.8 | 6.14 | 4.09 | 4.08 | 3.98 | 4.55 | 4.77 | 3.34 |
| SEL | 0.34 | 0.52 | 0.28 | 0 | 0.12 | 0.24 | 0.11 | 0.27 |
| Notes: | 12:08 | 12:18 | 12:31 | 12:37, sunny | 12:42 | 12:48 | 12:53 | 12:58 |
| TYSP | | 3 | | | | | 3 | 3 |
| PEVI | | 2 | 2 | 4 | 2 | | 2 | 4 |
| HIMO | | | | | | | | 3 |
| POAR | 6 | 7 | 9 | 7 | 4 | 7 | 8 | 8 |
| IMCA | 6 | 7 | 7 | 4 | | 5 | 7 | 6 |
| BILA | | | | | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | | | |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 2 | 4 | 1 | 2 | | | 3 | 2 |
| SCFL | | | 3 | 3 | | | 4 | |
| MISC | | | | | | | | |
| PIPU | | | 1 | 3 | 4 | 3 | | |
| PHAU | 7 | 6 | 4 | 7 | 5 | 4 | 4 | 4 |
| STPA? | 6 | | | | | | | |
| CASE | | | | | 6 | 4 | | |
| APAM | 4 | | | 6 | | | | |
| BOCY | | | 3 | 3 | | 5 | | |
| EUPSP | | 3 | | | | | | |
| CIMA | | | | | | | | |
| FRPE | | | | | | | | |
| MEAR | | | | | | | | |
| unknown6 | | | | | | | | |
| CUGR | 3 | | | | 1 | 3 | | |
| DEAD | 7 | 5 | 3 | 6 | 7 | 7 | 6 | 4 |
| WATER | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| BARE | 4 | 4 | 1 | 7 | 6 | 7 | 7 | 7 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 7 | 8 | 8 | 9 | 6 | 7 | 7 | 7 |
| NH3 (mg/L) | 1.16 | 0.44 | 16.48 | 5.4 | 1.08 | 1.53 | 1.75 | 20.48 |
| Total Nitrate | 1.4 | 1.3 | 1.8 | 3.3 | 4.3 | 5.2 | 1.2 | 0.1 |
| Total N | 11.25 | 15 | 18.75 | 15 | 11.25 | 15 | 11.25 | 105 |
| TP (mg/L) | 0.17 | 0.02 | 0.27 | 0.03 | 0.02 | 0 | 0 | 0.09 |

**Table D13. Raw vegetation data from each plot at the *Phragmites*-absent site on 8/24/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 4.34 | 6.49 | 5.21 | 4.86 | 7.4 | 2.8 | 4.36 |
| SEL | 0.32 | 0.25 | 0.1 | 0.55 | 0.1 | 0.24 | 0.02 |
| Notes: | 13:45 | 13:49 | 13:59 | 15:08 | 15:14 | 15:00 | 14:08, sunny |
| TYSP | 3 | 2 | 3 | 1 | | 3 | 3 |
| PEVI | 2 | | 2 | 4 | 3 | 5 | 4 |
| HIMO | 3 | 4 | 3 | | | | 4 |
| POAR | 9 | 10 | 9 | 8 | 10 | 7 | 6 |
| IMCA | 3 | 2 | 7 | 6 | 3 | 7 | 9 |
| BILA | | | | | | | |
| SISU | | | | | | 2 | |
| CIAR | | | | 2 | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | 1 | | 2 |
| AMCA | 1 | | | | | | |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| POAP | | | | | | | |
| unknown1 | | | | | | | |
| unknown6 | | | | | | | |
| CUGR | | | | 5 | | | |
| DEAD | 1 | 1 | 3 | 2 | 1 | 3 | 3 |
| WATER | 1 | 2 | 2 | 3 | 3 | 1 | 2 |
| BARE | 0 | 0 | 2 | 2 | 0 | 6 | 3 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 6 | 4 | 5 | 6 | 4 | 5 | 6 |
| NH3 (mg/L) | 0.22 | 1.54 | 0.35 | 1.34 | 0.35 | 2.3 | 0.1 |
| Total Nitrate | 1.2 | 0.8 | 1.4 | 0.8 | 1.3 | 0.1 | 0.7 |
| Total N | 15 | 18.75 | 11.25 | 11.25 | 11.25 | 11.25 | 18.75 |
| TP (mg/L) | 0.06 | 0.1 | 0.14 | 0.26 | 0.09 | 0.24 | 0.34 |

**Table D13 continued**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 6.9 | 4.42 | 3.31 | 4.35 | 5.12 | 4.86 | 5.36 | 4.73 |
| SEL | 0.22 | 0.06 | 0.57 | 0.26 | 0.04 | 0.3 | 0.06 | 0.13 |
| | | | | | | | | |
| Notes: | 15:21 | 14:16 | 14:51 | 14:23 | 14:30 | 14:46 | 14:33 | 14:39 |
| TYSP | 0 | 2 | 3 | 3 | 1 | 2 | | 3 |
| PEVI | 3 | 2 | 4 | 4 | 3 | 4 | 1 | 3 |
| HIMO | 3 | | | | | | | |
| POAR | 9 | 9 | 8 | 9 | 9 | 8 | 10 | 9 |
| IMCA | 1 | 5 | | 7 | 3 | 8 | 2 | |
| BILA | | 1 | | | | | | |
| SISU | 3 | | 4 | | | 4 | | |
| CIAR | | | 3 | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | 3 | | | | | | |
| AMCA | | | | 2 | | | | 2 |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | 5 |
| LIAR | | | | | | | | |
| ELOB | | | 2 | | | | | |
| SCTA | | | | 3 | | | | |
| NULU | | | | | | | | |
| ACCA | | | | | | | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| STPA? | | | | | | | | |
| CASE | | | | | | | | |
| APAM | | | | | | | | |
| BOCY | | | | | | | | |
| EUPSP | | | | | | | | |
| POAP | | | | | | | | |
| unknown1 | | | | | | | | |
| unknown6 | | | | | | | | |
| CUGR | | | 2 | | | | | |
| DEAD | 1 | 3 | 2 | 4 | 1 | 2 | 0 | 2 |
| WATER | 1 | 3 | 0 | 0 | 1 | 1 | 0 | 1 |
| BARE | 2 | 2 | 1 | 3 | 4 | 2 | 0 | 2 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 6 | 6 | 7 | 6 | 4 | 5 | 3 | 5 |
| NH3 (mg/L) | 2.29 | 0.4 | 1.11 | 5.42 | 0.43 | 8.04 | 1.11 | 0.17 |
| Total Nitrate | 1 | 0.9 | 1.1 | 0.7 | 1.1 | 1.3 | 1.3 | 1.1 |
| Total N | 7.5 | 7.5 | 11.25 | 15 | 3.75 | 18.75 | 3.75 | 11.25 |
| TP (mg/L) | 0.1 | 0.07 | 0.24 | 0.13 | 0.09 | 0.11 | 0.07 | 0.03 |

**Table D14. Raw vegetation data from each plot at the *Phragmites*-dominant site on 9/21/04.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 3.72 | 2.72 | 3.95 | 3.15 | 3.19 | 2.7 | 2.53 |
| SEL | 0.06 | 0.12 | 0.14 | 0.43 | 0.2 | 0.3 | 0 |
| Notes: | sunny, 11:24 | sunny, 11:04 | sunny, 11:18 | 11:38, sunny | sun, 11:33 | 11:44, sun | 11:50, sun |
| TYSP | 2 | | | | | | |
| PEVI | 2 | 4 | 2 | 4 | 2 | | 4 |
| HIMO | | | | | | | |
| POAR | 5 | 5 | 2 | 4 | 3 | 5 | 5 |
| IMCA | 6 | | 8 | 8 | 4 | 8 | 6 |
| BILA | | | | | | | 2 |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | 1 | | | | | |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | 3 | 3 | 2 | 3 | 3 | 2 |
| SCFL | | | | | | | |
| MISC | | | | | | 4 | |
| PIPU | | | | | | | 3 |
| PHAU | 6 | 8 | 5 | 7 | 9 | 7 | 8 |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | | 3 | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| SPEU | | | | | | | |
| Aster Sp | | | | | | | 2 |
| unknown6 | | | | | | | |
| CUGR | | | | 3 | | | |
| DEAD | 9 | 9 | 7 | 5 | 8 | 7 | 8 |
| WATER | 9 | 10 | 9 | 4 | 9 | 2 | 2 |
| BARE | 6 | 7 | 4 | 6 | 6 | 7 | 6 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 5 | 6 | 5 | 6 | 5 | 5 | 8 |
| NH3 (mg/L) | 0.21 | 1.33 | 2.59 | 0.55 | 2.88 | 6.4 | 0.43 |
| Total Nitrate | 1.7 | 1.3 | 1.8 | 1.7 | 0.8 | 2.2 | 2.5 |
| Total N | 11.25 | 11.25 | 67.5 | 15 | 7.5 | 18.75 | 11.25 |
| TP (mg/L) | 0.05 | 0.18 | 0.21 | 0.08 | 0.06 | 0.11 | 0.05 |

**Table D14 continued**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 3.67 | 3.8 | 3.56 | 3.93 | 3.19 | 2.63 | 4.38 | 2.4 |
| SEL | 0.47 | 0 | 0.19 | 0 | 0 | 0 | 0.03 | 0.05 |
| Notes: | 12:05, sun | 12:13, sun | 12:20, cloud | 12:26, cloud | 12:32, thin cloud | 12:36, thin cloud/ partly sunny | 12:40, thin cloud | 12:45, thin cloud, partly sunny |
| TYSP | 3 | | | | | | 2 | 3 |
| PEVI | | 6 | 3 | 4 | 2 | 1 | 3 | 6 |
| HIMO | | | | | | | | |
| POAR | 6 | 7 | 8 | 6 | 3 | 6 | 7 | 5 |
| IMCA | 4 | 7 | 7 | | 8 | 4 | 7 | 7 |
| BILA | | | | | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | | | |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 2 | 3 | | 2 | | | 2 | 3 |
| SCFL | | 1 | 1 | 3 | | | 3 | |
| MISC | | | | | 7 | | | |
| PIPU | | | | 3 | 4 | | | |
| PHAU | 7 | 5 | 3 | 4 | 3 | 2 | 2 | 2 |
| STPA? | 7 | | | | | | | |
| CASE | | | | | | | | |
| APAM | 4 | | | 5 | | | | |
| BOCY | | 4 | 4 | 3 | | | | |
| EUPSP | | 3 | | | | | | |
| MEAR | | | | | | 5 | | |
| SPEU | | | | | | | | |
| Aster Sp | | | | | | | | |
| unknown6 | | | | | | | | |
| CUGR | 3 | | | | 1 | | | |
| DEAD | 8 | 6 | 5 | 7 | 6 | 8 | 5 | 8 |
| WATER | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| BARE | 7 | 6 | 4 | 7 | 3 | 7 | 6 | 7 |
| PERL | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Species Richness | 8 | 8 | 6 | 8 | 7 | 5 | 7 | 6 |
| NH3 (mg/L) | 2.63 | 0.33 | 6.2 | 0.96 | 1.14 | 1.86 | 4.58 | 1.05 |
| Total Nitrate | 1.7 | 1.4 | 0.9 | 1.5 | 3.2 | 5.2 | 1.8 | 0.2 |
| Total N | 15 | 15 | 22.5 | 11.25 | 7.5 | 11.25 | 7.5 | 93.75 |
| TP (mg/L) | 0.18 | 0.06 | 0.09 | 0.02 | 0.03 | 0 | 0.03 | 0.13 |

**Table D15. Raw vegetation data from each plot at the Phragmites-absent site on 9/21/04.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 1.47 | 2.28 | 2.61 | 0.98 | 5.06 | 2.98 | 2.39 |
| SEL | 0 | 0.2 | 0.67 | 0 | 0.28 | 0 | 0.17 |
| Notes: | 14:14, sunny | 14:18 | 14:10, sunny | 15:06, sun | 15:10, sun | 15:02, sun | 14:22, sun |
| TYSP | 2 | 1 | 2 | 2 | | 4 | 2 |
| PEVI | 3 | 2 | 1 | 6 | | 6 | 3 |
| HIMO | | | 2 | | | | |
| POAR | 2 | 3 | 3 | 4 | 2 | 2 | 3 |
| IMCA | 5 | 1 | 8 | | 1 | 7 | 8 |
| BILA | | | | | | | |
| SISU | | | | | | | |
| CIAR | | | | 3 | | 2 | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | | | | | | |
| BIS5B | | | | | | | |
| SALA | | | | | 3 | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| LEVI | | | | | | | |
| BISPC | | | | | | | |
| POSA | | | | 2 | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| Aster Sp | | | | | | | |
| unknown6 | | | | | | | |
| CUGR | | | | | | | |
| DEAD | 8 | 9 | 8 | 8 | 10 | 7 | 6 |
| WATER | 1 | 1 | 2 | 4 | 1 | 4 | 3 |
| BARE | 6 | 1 | 5 | 4 | 1 | 6 | 7 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 4 | 4 | 5 | 5 | 3 | 5 | 4 |
| NH3 (mg/L) | 0.42 | 4.36 | 0.29 | 1.16 | 0.24 | 5.04 | 10.32 |
| Total Nitrate | 0.5 | 1.1 | 0.5 | 0.2 | 1.5 | 0.3 | 1.2 |
| Total N | 11.25 | 15 | 11.25 | 11.25 | 11.25 | 3.75 | 22.5 |
| TP (mg/L) | 0.14 | 0.26 | 0.13 | 0.17 | 0.13 | 0.03 | 0.45 |

**Table D15 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 2.04 | 2.43 | 2.54 | 1.33 | 1 | 2.09 | 2.05 | 2.09 |
| SEL | 0.19 | 0.37 | 0.25 | 0 | 0 | 0.46 | 0.16 | 0.07 |
| Notes: | 14:58, sun | 14:27, sun | 14:55, sun | 14:34, sun | 14:37, sun | 14:50, sun | 14:40, sun | 14:45, sun |
| TYSP | | | 5 | 4 | 3 | 2 | 2 | 2 |
| PEVI | 4 | 4 | 6 | 4 | 4 | 5 | 2 | 4 |
| HIMO | | | | | | | | |
| POAR | 3 | 2 | 2 | | 6 | 4 | 1 | 6 |
| IMCA | 3 | | 3 | | | 8 | 3 | |
| BILA | | | | | | | | |
| SISU | | | | | | | | |
| CIAR | | 1 | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | 3 | | |
| BIS5B | | | | | | | | |
| SALA | 2 | | | | | | | 2 |
| LIAR | | | | | | | | |
| ELOB | | | 3 | | | | | |
| SCTA | | | | 1 | | | | 1 |
| NULU | | | | | | | | |
| ACCA | | | | | | | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| LEVI | | | | | | | | |
| BISPC | | | | | | | | |
| POSA | | | | | | | | |
| ASSP | | | | | | | | |
| STPA2 | | | | | | | | |
| Aster Sp | | | | | | | | |
| CUGR | | | | | | | | |
| DEAD | 8 | 9 | 7 | 9 | 8 | 8 | 10 | 9 |
| WATER | 1 | 2 | 5 | 3 | 2 | 2 | 1 | 3 |
| BARE | 3 | 5 | 5 | 6 | 7 | 3 | 2 | 3 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 4 | 3 | 5 | 3 | 3 | 6 | 4 | 5 |
| NH3 (mg/L) | 1.41 | 0.67 | 1.16 | 8.6 | 0.29 | 0.58 | 0.91 | 0.14 |
| Total Nitrate | 1.2 | 1 | 1.8 | 1.4 | 1.2 | 1.4 | 0.9 | 1 |
| Total N | 11.25 | 15 | 18.75 | 18.75 | 11.25 | 26.25 | 15 | 3.75 |
| TP (mg/L) | 0.03 | 0.06 | 0.32 | 0.05 | 0.06 | 0.06 | 0.1 | 0.08 |

**Table D16. Raw vegetation data from each plot at the *Phragmites*-dominant site on 6/06/05.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 2.35 | 3.49 | 3.36 | 4.96 | 3.75 | 5.15 | 7.92 |
| SEL | 0 | 0.41 | 0.83 | 0.33 | 0.04 | 0.35 | 0.13 |
| | 12:58 | 13:14 | 13:26 | 13:32 | 13:38 | 13:47 | 13:52 |
| Notes: | clear | clear | clear | clear | clear | clear | clear |
| TYSP | | | | | | | |
| PEVI | 4 | 6 | 5 | 7 | | 3 | 7 |
| HIMO | | | 2 | | | | |
| POAR | | | | | 5 | 3 | 3 |
| IMCA | 4 | | 4 | 8 | 7 | 9 | 7 |
| BILA | | | | | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | | | | | 1 | |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 7 | 7 | 6 | 5 | 7 | 4 | 4 |
| SCFL | 4 | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | 4 | 6 | 9 | 9 | 9 | 7 | 9 |
| STPA? | | | | | | | |
| CASE | | | | | | 4 | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| EUPSP | | | | | | | |
| CIMA | | | | | | | |
| FRPE | | | | | | | |
| MEAR | | | | | | | |
| Aster Sp | | | | | | | |
| CUGR | | | | | | | |
| DEAD | 5 | 4 | 1 | 3 | 6 | 3 | 3 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 7 | 2 | 6 | 0 | 0 | 0 | 0 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 5 | 3 | 5 | 4 | 4 | 7 | 5 |
| NH3 (mg/L) | 1.14 | 4.88 | 4.3 | 0.65 | 0.79 | 6.08 | 0.57 |
| Total Nitrate | 3.2 | | 2.4 | 7 | 3.9 | 6.7 | 3.1 |
| Total N | | | | | | | |
| TP (mg/L) | 0.12 | 0.58 | 0.58 | 0.18 | 0.14 | 0.36 | 0.09 |
| max ht (cm) | 180 | 160 | 210 | 220 | 240 | 230 | 250 |
| avg ht (cm) | 110 | 120 | 200 | 190 | 200 | 190 | 200 |

**Table D16 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 4.84 | 3.82 | 6.34 | 4.14 | 4.78 | 5.09 | 4.74 | 5.55 |
| SEL | 0.52 | 0.05 | 0.11 | 0.28 | 0.41 | 0.23 | 0.13 | 0.38 |
| Notes: | 14:33 clear | 14:40 clear | 14:46 clear | 14:50 clear | 14:56 clear | 15:01 clear | 15:08 clear | 15:15 clear |
| TYSP | 1 | | | | | | | 2 |
| PEVI | | 7 | 6 | 7 | 3 | | 6 | 6 |
| HIMO | | | | | | | | |
| POAR | 6 | | 3 | 4 | 3 | 2 | 4 | 3 |
| IMCA | 8 | 1 | 8 | 8 | 8 | 9 | 7 | 5 |
| BILA | 4 | 2 | | | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | 2 | | |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | | 7 | 5 | 1 | 4 | | 3 | 5 |
| SCFL | | 3 | | | | 3 | 5 | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | 9 | 8 | 8 | 7 | 8 | 8 | 8 | 9 |
| STPA? | | | | | | 4 | | |
| CASE | | 2 | 3 | 3 | 3 | 4 | | |
| APAM | 1 | | | 3 | 2 | | | |
| BOCY | | | | 3 | 2 | | | |
| EUPSP | | | | | | | | |
| CIMA | | | | | | | | |
| FRPE | | | | | | | | |
| MEAR | | | | | | | | |
| Aster Sp | | | | | | | | |
| CUGR | | | | | | 2 | | |
| DEAD | 3 | 2 | 2 | 4 | 4 | 5 | 3 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 6 | 7 | 6 | 8 | 8 | 8 | 6 | 6 |
| NH3 (mg/L) | 0.71 | 0.87 | 1.56 | 1.14 | 1.06 | 3.3 | 1.3 | 16.88 |
| Total Nitrate | 2.4 | 3.4 | 8.8 | 1.7 | 4.5 | 5.8 | 2.5 | 1.3 |
| Total N | | | | | | | | |
| TP (mg/L) | 0.21 | 0.35 | 0.88 | 0.05 | 0.08 | 0.34 | 0.04 | 0.96 |
| max ht (cm) | 270 | 240 | 210 | 210 | 240 | 200 | 240 | 240 |
| avg ht (cm) | 200 | 160 | 160 | 140 | 160 | 140 | 170 | 170 |

**Table D17. Raw vegetation data from each plot at the Phragmites-absent site on 6/06/05.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 3.71 | 4.32 | 6.3 | 5.73 | 3.55 | 4.77 | 4.24 |
| SEL | 0.68 | 0.64 | 0.11 | 0.52 | 0.21 | 0.03 | 0.26 |
| Notes: | 10:30 clear | 10:34 clear | 10:41 clear | 12:00 clear | 12:05 clear | 11:54 clear | 10:52 clear |
| TYSP | | 4 | 2 | 2 | 1 | 6 | 4 |
| PEVI | 10 | 9 | 9 | 7 | 8 | 8 | 8 |
| HIMO | 2 | | | | | | |
| POAR | 3 | 3 | 5 | 2 | | 6 | 7 |
| IMCA | 5 | 6 | 6 | 6 | 3 | 3 | 7 |
| BILA | | | 2 | | | | |
| SISU | | | | | | | 4 |
| CIAR | | | 2 | 1 | | 2 | |
| LEOR | | | | | | | 2 |
| ZIAQ | | | | | | | 2 |
| AMCA | | 2 | | | | | |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 2 | | | | 2 | 1 | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | | | | | |
| LEVI | | | | | | | |
| BISPC | | | | | | | |
| POSA | | | | | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| SPEU | | | | | | | |
| Aster Sp | | | | | | | |
| unknown6 | | | | | | | |
| Sparganium | | | | | | | |
| CUGR | | | | | | | |
| DEAD | 0 | 0 | 2 | 0 | 4 | 0 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| BARE | 0 | 0 | 0 | 3 | 6 | 1 | 1 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 5 | 5 | 6 | 5 | 4 | 6 | 7 |
| NH3 (mg/L) | 0.76 | 1.35 | 0.64 | 9.8 | 1.28 | 4.98 | 21.28 |
| Total Nitrate | 3.5 | 2.8 | 1.1 | 2.2 | 1.6 | 1.7 | 0 |
| Total N | | | | | | | |
| TP (mg/L) | 0.22 | 1.16 | 0.26 | 0.37 | 0.75 | 0.21 | 0.56 |
| max ht (cm) | 110 | 160 | 150 | 130 | 120 | 170 | 160 |
| avg ht (cm) | 90 | 120 | 90 | 90 | 95 | 120 | 100 |

**Table D17 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 7.24 | 7.23 | 5.67 | 5.36 | 4.73 | 6.23 | 4.58 | 4.27 |
| SEL | 0.19 | 0.35 | 0.11 | 0.06 | 0.6 | 0.02 | 0.08 | 0.21 |
| | 11:49 | 11:01 | 11:42 | 11:08 | 11:15 | 11:34 | 11:20 | 11:27 |
| Notes: | clear | clear | clear | clear | clear | clear | clear | clear |
| TYSP | | 1 | 4 | 3 | 2 | 4 | 3 | 1 |
| PEVI | 8 | 8 | 8 | 8 | 7 | 9 | 10 | 9 |
| HIMO | | | | | | | | |
| POAR | 5 | 7 | 4 | 3 | 4 | 4 | 4 | 4 |
| IMCA | 8 | 6 | 4 | 8 | 5 | 8 | 2 | 2 |
| BILA | | | | | | | | |
| SISU | | 3 | 4 | | 4 | 3 | | |
| CIAR | 3 | | 5 | | | | | 2 |
| LEOR | | 1 | | 1 | | | | |
| ZIAQ | | 2 | | 2 | | | | |
| AMCA | | 2 | | | | | | |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | 3 | | | | | |
| SCTA | | | 2 | 3 | 1 | | | |
| NULU | | | | | | | 4 | |
| ACCA | | | 2 | | | | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| POSA | | | | | | | | |
| ASSP | | | | | | | | |
| SPEU | | | | | | | | |
| Aster Sp | | | | | | | | |
| CUGR | | | | | | | | |
| DEAD | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| WATER | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| BARE | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 4 |
| PERL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Species Richness | 4 | 8 | 9 | 7 | 6 | 6 | 5 | 5 |
| NH3 (mg/L) | 5.48 | 0.88 | 4.28 | 0.18 | 0.48 | 7.84 | 1.5 | 2.59 |
| Total Nitrate | 1.8 | 0.1 | 2.7 | 1 | | 1.5 | 8.6 | |
| Total N | | | | | | | | |
| TP (mg/L) | 0.65 | 0.28 | 1.2 | 0.12 | 0.09 | 0.44 | 0.73 | 1.04 |
| max ht (cm) | 110 | 100 | 190 | 180 | 115 | 180 | 125 | 100 |
| avg ht (cm) | 100 | 80 | 100 | 95 | 90 | 110 | 95 | 95 |

**Table D18. Raw vegetation data from each plot at the *Phragmites*-dominant site on 8/02/05.**

| plot # | 15M003 | 14M112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 |
|---|---|---|---|---|---|---|---|
| LAI | 2.14 | 3.66 | 3.61 | 5.48 | 5.33 | 5.18 | 3.52 |
| SEL | 0.04 | 0.05 | 0.06 | 0.17 | 0.05 | 0.41 | 0.1 |
| Notes: | 10:02 v. sunny | 10:18 v sunny | 10:26 v sunny | 10:44 v sunny | 10:37 | 11:02 v sunny | 10:52 v sunny |
| TYSP | 3 | | | | | | |
| PEVI | 4 | 6 | 5 | 3 | | 3 | 4 |
| HIMO | | | 2 | | | | |
| POAR | 5 | 6 | 7 | | 7 | 3 | |
| IMCA | 1 | | 6 | 9 | 7 | 6 | 6 |
| BILA | | | | | | | |
| SISU | | | | | | | |
| CIAR | | | | | | | |
| LEOR | | | | | | | |
| ZIAQ | | | | | | | |
| AMCA | | | | | | | 3 |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | | | | | |
| NULU | | | | | | | |
| ACCA | 5 | 4 | 4 | 2 | 3 | 3 | 3 |
| SCFL | 6 | 5 | | | | | |
| MISC | | 2 | | | | 2 | |
| PIPU | | | | | | | |
| PHAU | 4 | 8 | 8 | 9 | 9 | 9 | 9 |
| STPA? | | | | | | | |
| CASE | 3 | | | | | | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| MEAR | | | | | | | |
| POSA | | | | | | | |
| ASSP | | | | | | | |
| STPA2 | | | | | | | |
| CUGR | | | 2 | | 2 | 1 | |
| DEAD | 1 | 2 | 2 | 3 | 4 | 4 | 5 |
| WATER | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| BARE | 4 | 1 | 3 | 1 | 0 | 1 | 3 |
| PERL | | | | | | | |
| Species Richness | 8 | 6 | 7 | 4 | 5 | 7 | 5 |
| | | | | | | | |
| NH3 (mg/L) | 0.41 | 1.04 | 0.73 | 16.56 | 0.67 | | |
| Total Nitrate | 1.6 | 1.5 | 1.6 | 9.8 | 0.7 | | 0 |
| max ht (cm) | 200 | 240 | 290 | 325 | 300 | 325 | 315 |
| avg ht (cm) | 150 | 190 | 150 | 200 | 180 | 250 | 210 |

**Table D18 continued.**

| plot # | 8m113 | 7m102 | 6m222 | 5M111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|
| LAI | 4.43 | 4.14 | 3.98 | 5.55 | 3.46 | 4.75 | 4.1 | 4.11 |
| SEL | 0.02 | 0.25 | 0.33 | 0.05 | 0.02 | 0.04 | 0.05 | 0.08 |
| Notes: | 11:16 v sunny | 11:27 v sunny | 11:35 vs unny | 11:43 v sunny | 11:40 v sunny | 11:58 v sunny | 12:17 v sunny | 12:11 v sunny |
| TYSP | | | | | | | 2 | 3 |
| PEVI | 1 | 4 | 4 | 5 | | | 7 | 3 |
| HIMO | | 1 | | | | | | 2 |
| POAR | 3 | 5 | 6 | 2 | | 4 | 3 | 6 |
| IMCA | 6 | 8 | 9 | 8 | 8 | 8 | 6 | 8 |
| BILA | | | | | | | | |
| SISU | | | | | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | | | | | | | | |
| AMCA | | | | | | 3 | | |
| BIS5B | | | | | | | | |
| SALA | | | | | | | | |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | | | | | | | |
| NULU | | | | | | | | |
| ACCA | 3 | 4 | 3 | 3 | 3 | | 4 | 4 |
| SCFL | | 2 | 3 | 3 | | 3 | 3 | |
| MISC | | 2 | | | | | | |
| PIPU | | | | | | | | |
| PHAU | 9 | 9 | 4 | 9 | 7 | 5 | 8 | 7 |
| STPA? | 4 | | | | | | | |
| CASE | | | | | 2 | 8 | | |
| APAM | 2 | | | 7 | 2 | | | |
| BOCY | | | 4 | 3 | 2 | 5 | | |
| MEAR | | | | | | 4 | | |
| POSA | | 2 | | | | | | |
| ASSP | | | | | | | | |
| STPA2 | | | | | | | | |
| CUGR | 2 | | 2 | 1 | 2 | 2 | | |
| DEAD | 4 | 3 | 2 | 3 | 5 | 1 | 2 | 2 |
| WATER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BARE | 1 | 2 | 1 | 1 | 4 | 2 | 2 | 3 |
| PERL | | | | | | | | |
| Species Richness | 8 | 9 | 8 | 9 | 7 | 9 | 7 | 7 |
| | | | | | | | | |
| NH3 (mg/L) | 36.8 | 0.99 | | 14.8 | 0.62 | | 2.63 | 18.8 |
| Total Nitrate | 4 | 2.1 | | 6.4 | 1.5 | | 2 | |
| max ht (cm) | 300 | 300 | 190 | 290 | 310 | 250 | 310 | 290 |
| avg ht (cm) | 200 | 190 | 150 | 200 | 200 | 140 | 175 | 150 |

**Table D19. Raw vegetation data from each plot at the Phragmites-absent site on 8/02/05.**

| plot # | 1d001 | 2d101 | 3d002 | 4d111 | 5d112 | 6d201 | 7d102 |
|---|---|---|---|---|---|---|---|
| LAI | 1.34 | 3.67 | 4.28 | 1.5 | 3.14 | 4.96 | 3.92 |
| SEL | 0.27 | 0.32 | 0.37 | 0.39 | 0.17 | 0.07 | 0.06 |
| | 13:29 | 13:37 | 13:42 | 14:42 | 14:46 | 14:36 | 13:50 |
| | v | v | v | v | v | v | v |
| Notes: | sunny | sunny | sunny | sunny | sunny | sunny | sunny |
| TYSP | | 5 | 2 | 3 | | 6 | 1 |
| PEVI | 6 | 6 | 2 | 6 | 5 | 2 | 3 |
| HIMO | 4 | | | | 7 | | |
| POAR | 6 | 6 | 8 | 6 | 8 | 10 | 9 |
| IMCA | 7 | 8 | 7 | 6 | | 1 | 6 |
| BILA | | | | | | | |
| SISU | 3 | | | | 3 | | |
| CIAR | | | 1 | | | | |
| LEOR | | | | 1 | | | |
| ZIAQ | | | | | 4 | 2 | |
| AMCA | 2 | | | | | | |
| BIS5B | | | | | | | |
| SALA | | | | | | | |
| LIAR | | | | | | | |
| ELOB | | | | | | | |
| SCTA | | | 1 | | | | |
| NULU | | | | | | | |
| ACCA | 1 | | | | | | |
| SCFL | | | | | | | |
| MISC | | | | | | | |
| PIPU | | | | | | | |
| PHAU | | | 1 | | | | |
| STPA? | | | | | | | |
| CASE | | | | | | | |
| APAM | | | | | | | |
| BOCY | | | | | | | |
| Sparganium | | | | | | | |
| CUGR | | | 1 | 5 | 2 | | 2 |
| DEAD | 2 | 3 | 2 | 3 | 1 | 1 | 3 |
| WATER | 0 | 1 | 0 | 2 | 0 | 0 | 0 |
| BARE | 3 | 4 | 1 | 6 | 2 | 0 | 2 |
| PERL | | | | | | | |
| Species Richness | 7 | 4 | 8 | 6 | 6 | 5 | 5 |
| | | | | | | | |
| NH3 (mg/L) | 0.52 | 4.78 | 0.72 | 4.74 | 2.94 | 5.04 | 19.52 |
| Total Nitrate | 1 | 1.1 | 1.1 | 0.8 | 0.1 | 0.8 | 0.1 |
| max ht (cm) | 130 | 210 | 170 | 110 | 210 | 210 | 140 |
| avg ht (cm) | 100 | 130 | 120 | 70 | 110 | 150 | 110 |

**Table D19 continued.**

| plot # | 8d221 | 9d202 | 10d203 | 11d222 | 12d103 | 13d223 | 14d113 | 15d003 |
|---|---|---|---|---|---|---|---|---|
| LAI | 4.17 | 4.53 | 3.36 | 3.96 | 3.4 | 3.91 | 3.97 | 4.24 |
| SEL | 0.08 | 0.11 | 0.14 | 0.23 | 0.04 | 0.06 | 0.07 | 0.1 |
| Notes: | 14:51 v sunny | 13:51 v sunny | 14:32 v sunny | 14:26 v sunny | 14:03 v sunny | 14:21 | 14:11 v sunny | 14:16 v sunny |
| TYSP | | 1 | 6 | 4 | 1 | 3 | 2 | 1 |
| PEVI | 5 | 4 | 5 | 6 | 3 | 4 | 4 | 5 |
| HIMO | 4 | | | | | | | |
| POAR | 7 | 9 | 9 | 8 | 9 | 9 | 9 | 9 |
| IMCA | 9 | 4 | 6 | 2 | 9 | 8 | 6 | |
| BILA | 5 | | | | | | | |
| SISU | | | | 3 | | | | |
| CIAR | | | | | | | | |
| LEOR | | | | | | | | |
| ZIAQ | 4 | 3 | | | 1 | | | 1 |
| AMCA | | | | | 2 | | | |
| BIS5B | | | | | | | | |
| SALA | 2 | | | | | | | 7 |
| LIAR | | | | | | | | |
| ELOB | | | | | | | | |
| SCTA | | 2 | | 3 | 1 | | | |
| NULU | | | | | | | 5 | |
| ACCA | | | | | | 2 | | |
| SCFL | | | | | | | | |
| MISC | | | | | | | | |
| PIPU | | | | | | | | |
| PHAU | | | | | | | | |
| STPA? | | | | | | | | |
| CASE | | | | | | | | |
| APAM | | | | | | | | |
| BOCY | | | | | | | | |
| Sparganium | | | | | | | | |
| CUGR | 2 | 2 | | 7 | | 1 | | 2 |
| DEAD | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 2 |
| WATER | 0 | 0 | 0 | 1 | 3 | 1 | 2 | 5 |
| BARE | 1 | 1 | 1 | 3 | 2 | 0 | 3 | 0 |
| PERL | | | | | | | | |
| Species Richness | 8 | 7 | 4 | 7 | 7 | 6 | 5 | 6 |
| NH3 (mg/L) | 34.24 | 1.95 | 2.94 | 1.31 | | 0.3 | 0.85 | 0.37 |
| Total Nitrate | 0.5 | 0.4 | 0.8 | 1.6 | | 0.3 | 1.1 | 1.1 |
| max ht (cm) | 170 | 180 | 200 | 210 | 140 | 190 | 190 | 120 |
| avg ht (cm) | 130 | 100 | 130 | 150 | 110 | 130 | 110 | 95 |

**Table D20. Diversity data from each plot at the *Phragmites*-dominant site. Diversity index was calculated with the percent cover of each species and the total percent cover of all species.**

| | 15m003 | 14m112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 | 8m113 | 7m102 | 6m222 | 5m111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | 1.73 | 1.40 | 1.76 | 1.42 | 1.46 | 1.48 | 1.63 | 1.52 | 1.58 | 1.71 | 1.84 | 1.56 | 1.74 | 1.72 | 1.68 |
| 6/3/2004 | 1.25 | 1.11 | 1.67 | 0.84 | 1.14 | 1.22 | 0.91 | 1.04 | 1.55 | 1.77 | 0.86 | 1.05 | 1.10 | 1.55 | 1.57 |
| 6/16/2004 | 1.63 | 1.78 | 1.78 | 1.64 | 1.43 | 1.71 | 1.72 | 1.58 | 1.88 | 1.94 | 1.78 | 1.70 | 1.65 | 2.03 | 1.75 |
| 6/29/2004 | 1.54 | 1.40 | 1.60 | 1.67 | 1.15 | 1.42 | 1.58 | 1.34 | 1.95 | 1.88 | 2.11 | 1.67 | 1.44 | 1.54 | 1.53 |
| 7/19/2004 | 1.35 | 1.36 | 1.24 | 1.42 | 1.33 | 1.30 | 1.41 | 1.37 | 1.80 | 1.12 | 1.58 | 1.61 | 1.37 | 1.51 | 1.72 |
| 8/24/2004 | 0.92 | 1.57 | 1.31 | 1.33 | 1.55 | 1.43 | 1.75 | 1.76 | 1.64 | 0.92 | 1.82 | 1.51 | 1.67 | 1.54 | 1.39 |
| 9/21/2004 | 1.46 | 1.51 | 1.30 | 1.48 | 1.39 | 1.59 | 1.52 | 1.74 | 1.83 | 1.20 | 1.62 | 1.27 | 1.27 | 1.43 | 1.52 |
| 6/6/2005 | 1.41 | 1.20 | 1.10 | 1.21 | 1.36 | 0.99 | 1.18 | 1.07 | 1.20 | 1.24 | 1.38 | 1.09 | 1.11 | 1.34 | 0.97 |
| 8/2/2005 | 1.78 | 1.23 | 1.35 | 0.80 | 1.16 | 0.81 | 0.97 | 0.89 | 1.13 | 0.99 | 1.33 | 1.13 | 1.33 | 1.25 | 1.28 |

**Table D21. Diversity data from each plot at the *Phragmites*-absent site**

| | 15m003 | 14m112 | 13m202 | 12m223 | 11m002 | 10m203 | 9m103 | 8m113 | 7m102 | 6m222 | 5m111 | 4m001 | 3m101 | 2m201 | 1m221 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/25/2004 | 1.73 | 1.40 | 1.76 | 1.42 | 1.46 | 1.48 | 1.63 | 1.52 | 1.58 | 1.71 | 1.84 | 1.56 | 1.74 | 1.72 | 1.68 |
| 6/3/2004 | 1.25 | 1.11 | 1.67 | 0.84 | 1.14 | 1.22 | 0.91 | 1.04 | 1.55 | 1.77 | 0.86 | 1.05 | 1.10 | 1.55 | 1.57 |
| 6/16/2004 | 1.63 | 1.78 | 1.78 | 1.64 | 1.43 | 1.71 | 1.72 | 1.58 | 1.88 | 1.94 | 1.78 | 1.70 | 1.65 | 2.03 | 1.75 |
| 6/29/2004 | 1.54 | 1.40 | 1.60 | 1.67 | 1.15 | 1.42 | 1.58 | 1.34 | 1.95 | 1.88 | 2.11 | 1.67 | 1.44 | 1.54 | 1.53 |
| 7/19/2004 | 1.35 | 1.36 | 1.24 | 1.42 | 1.33 | 1.30 | 1.41 | 1.37 | 1.80 | 1.12 | 1.58 | 1.61 | 1.37 | 1.51 | 1.72 |
| 8/24/2004 | 0.92 | 1.57 | 1.31 | 1.33 | 1.55 | 1.43 | 1.75 | 1.76 | 1.64 | 0.92 | 1.82 | 1.51 | 1.67 | 1.54 | 1.39 |
| 9/21/2004 | 1.46 | 1.51 | 1.30 | 1.48 | 1.39 | 1.59 | 1.52 | 1.74 | 1.83 | 1.20 | 1.62 | 1.27 | 1.27 | 1.43 | 1.52 |
| 6/6/2005 | 1.41 | 1.20 | 1.10 | 1.21 | 1.36 | 0.99 | 1.18 | 1.07 | 1.20 | 1.24 | 1.38 | 1.09 | 1.11 | 1.34 | 0.97 |
| 8/2/2005 | 1.78 | 1.23 | 1.35 | 0.80 | 1.16 | 0.81 | 0.97 | 0.89 | 1.13 | 0.99 | 1.33 | 1.13 | 1.33 | 1.25 | 1.28 |

**Table D22. Leaf nutrient data for the six species most present at each plot at the *Phragmites*-dominant site. The first number in each description code designates the plot number of the sample. The first letter indicates which site the sample was taken from: M = *Phragmites*-dominant site; D = *Phragmites*-absent site. The last four letters are the species code of the sample. Table D1 explains each species code.**

| Description | Lab# | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | B (ppm) | Fe (ppm) | Mn (ppm) | Cu (ppm) | Zn (ppm) | Al (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1MACCA | 1 | 1.83 | 0.360 | 2.64 | 0.52 | 0.515 | 0.336 | 17.3 | 388.2 | 845.1 | 6.3 | 25.7 | 118.5 |
| 1MHIMO | 2 | 2.61 | 0.285 | 1.71 | 0.98 | 0.679 | 0.235 | 25.0 | 300.0 | 470.1 | 4.2 | 29.3 | 43.4 |
| 1MIMCA | 3 | 2.96 | 0.282 | 3.79 | 1.26 | 0.595 | 0.188 | 33.9 | 752.2 | 452.5 | 3.1 | 53.6 | 220.4 |
| 1MPEVI | 4 | 3.52 | 0.715 | 4.47 | 1.59 | 0.386 | 0.341 | 46.1 | 1584.2 | 1009.0 | 15.4 | 77.3 | 505.3 |
| 1MPHAU | 5 | 1.29 | 0.114 | 0.66 | 0.10 | 0.066 | 0.119 | 7.3 | 118.9 | 113.0 | 11.9 | 18.9 | 69.0 |
| 1MPOAR | 6 | 2.59 | 0.327 | 2.14 | 0.67 | 0.631 | 0.206 | 33.6 | 1827.3 | 1995.0 | 15.6 | 59.1 | 565.6 |
| 1MTYSP | 7 | 1.76 | 0.358 | 2.44 | 0.63 | 0.555 | 0.351 | 26.5 | 860.2 | 931.1 | 11.0 | 36.8 | 326.2 |
| 2MACCA | 8 | 1.89 | 0.365 | 2.72 | 0.63 | 0.554 | 0.347 | 28.4 | 485.9 | 1145.0 | 16.2 | 33.9 | 240.3 |
| 2MPEVI | 9 | 3.68 | 0.769 | 6.09 | 1.60 | 0.319 | 0.330 | 46.8 | 1008.8 | 1529.3 | 8.8 | 84.9 | 495.6 |
| 2MPHAU | 10 | 1.74 | 0.145 | 0.58 | 0.19 | 0.113 | 0.162 | 5.4 | 178.7 | 285.4 | 13.2 | 45.7 | 69.7 |
| 2MSCFL | 11 | 1.49 | 0.275 | 1.34 | 0.19 | 0.210 | 0.182 | 12.3 | 355.9 | 1401.2 | 39.6 | 46.9 | 147.7 |
| 2MTUSP | 12 | 1.38 | 0.213 | 1.21 | 0.58 | 0.488 | 0.209 | 18.2 | 339.3 | 1715.7 | 10.7 | 23.9 | 193.6 |
| 3MBOCY | 13 | 1.84 | 0.241 | 1.79 | 1.79 | 0.496 | 0.311 | 37.2 | 74.9 | 184.2 | 8.9 | 40.3 | 74.4 |
| 3MCASE | 14 | 1.85 | 0.306 | 1.75 | 0.83 | 0.681 | 0.210 | 35.6 | 70.5 | 260.0 | 8.8 | 27.1 | 50.8 |
| 3MIMCA | 15 | 2.07 | 0.361 | 3.35 | 1.83 | 0.706 | 0.319 | 22.4 | 100.8 | 193.0 | 7.5 | 100.0 | 50.1 |
| 3MMEAR | 16 | 1.72 | 0.243 | 2.06 | 0.71 | 0.428 | 0.238 | 22.8 | 72.0 | 227.3 | 12.8 | 37.8 | 18.3 |
| 3MPHAU | 17 | 1.58 | 0.124 | 0.70 | 0.16 | 0.086 | 0.139 | 5.1 | 89.5 | 303.6 | 12.3 | 21.8 | 18.4 |
| 4MACCA | 18 | 2.58 | 0.289 | 1.57 | 0.69 | 0.597 | 0.257 | 28.8 | 123.1 | 635.2 | 4.2 | 21.8 | 77.2 |
| 4MCASE | 19 | 2.00 | 0.267 | 2.02 | 0.79 | 0.582 | 0.188 | 36.5 | 66.7 | 261.7 | 6.4 | 18.0 | 23.8 |
| 4MCUGR | 20 | 1.43 | 0.235 | 1.81 | 0.47 | 0.224 | 0.160 | 23.8 | 505.9 | 139.7 | 42.9 | 396.3 | 61.5 |
| 4MIMCA | 21 | 2.68 | 0.385 | 3.76 | 1.40 | 0.759 | 0.266 | 26.9 | 128.2 | 179.4 | 6.4 | 80.6 | 51.0 |
| 4MPHAU | 22 | 1.04 | 0.082 | 0.54 | 0.13 | 0.065 | 0.097 | 3.6 | 63.6 | 277.8 | 5.3 | 12.4 | 24.6 |
| 5MAPAM | 23 | 2.53 | 0.247 | 1.70 | 1.40 | 0.384 | 0.192 | 20.7 | 78.5 | 248.7 | 11.8 | 41.5 | 23.6 |
| 5MCASE | 24 | 2.61 | 0.218 | 2.57 | 1.05 | 0.557 | 0.195 | 36.2 | 67.7 | 192.4 | 8.3 | 32.4 | 17.6 |
| 5MIMCA | 25 | 2.55 | 0.245 | 3.68 | 1.36 | 0.570 | 0.179 | 21.0 | 100.8 | 136.2 | 5.1 | 91.4 | 35.3 |
| 5MPHAU | 26 | 2.18 | 0.188 | 1.02 | 0.21 | 0.111 | 0.202 | 5.3 | 83.0 | 296.4 | 12.4 | 22.0 | 27.7 |
| 5MSCFL | 27 | 1.30 | 0.219 | 1.88 | 0.19 | 0.149 | 0.165 | 11.2 | 92.3 | 928.7 | 39.1 | 37.7 | 30.6 |
| 6MACCA | 28 | 1.95 | 0.319 | 2.74 | 0.70 | 0.550 | 0.298 | 18.4 | 410.5 | 691.5 | 14.7 | 36.5 | 224.5 |
| 6MIMCA | 29 | 2.05 | 0.244 | 3.37 | 1.10 | 0.625 | 0.178 | 18.7 | 570.4 | 240.5 | 7.2 | 75.4 | 264.0 |
| 6MPEVI | 30 | 3.62 | 0.679 | 5.22 | 1.50 | 0.413 | 0.323 | 66.2 | 1827.5 | 1363.8 | 5.3 | 93.1 | 711.5 |
| 6MPHAU | 31 | 1.53 | 0.148 | 0.96 | 0.13 | 0.092 | 0.148 | 5.8 | 150.2 | 228.7 | 16.2 | 19.7 | 50.3 |
| 6MSCFL | 32 | 1.42 | 0.260 | 1.34 | 0.16 | 0.188 | 0.157 | 5.8 | 179.0 | 1309.5 | 25.2 | 36.7 | 66.7 |
| 7MACCA | 33 | 1.73 | 0.275 | 3.27 | 0.78 | 0.529 | 0.322 | 21.1 | 216.8 | 789.4 | 7.1 | 27.0 | 66.7 |
| 7MIMCA | 34 | 3.24 | 0.283 | 3.86 | 1.18 | 0.446 | 0.214 | 20.7 | 1109.4 | 321.0 | 11.9 | 81.8 | 328.6 |
| 7MPEVI | 35 | 3.66 | 0.512 | 4.60 | 1.79 | 0.326 | 0.352 | 52.4 | 581.0 | 1980.6 | 6.8 | 78.9 | 228.9 |
| 7MPHAU | 36 | 1.10 | 0.110 | 0.61 | 0.11 | 0.058 | 0.122 | 3.8 | 88.6 | 175.5 | 9.8 | 17.4 | 35.6 |

**Table D22 continued.**

| Description | Lab# | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | B (ppm) | Fe (ppm) | Mn (ppm) | Cu (ppm) | Zn (ppm) | Al (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8MAPAM | 37 | 0.00 | 0.274 | 1.52 | 0.97 | 0.443 | 0.209 | 23.8 | 210.6 | 395.0 | 9.3 | 32.8 | 53.8 |
| 8MIMCA | 38 | 3.49 | 0.246 | 3.35 | 0.98 | 0.525 | 0.175 | 22.9 | 121.1 | 202.4 | 4.7 | 55.9 | 52.5 |
| 8MPHAU | 39 | 1.04 | 0.058 | 0.35 | 0.08 | 0.041 | 0.087 | 5.8 | 49.2 | 83.2 | 7.3 | 11.8 | 75.3 |
| 8MPOAR | 40 | 2.56 | 0.287 | 2.30 | 0.66 | 0.810 | 0.220 | 43.6 | 1013.2 | 1509.5 | 7.3 | 109.4 | 538.7 |
| 8MTYSP | 41 | 2.74 | 0.378 | 2.78 | 0.68 | 0.566 | 0.269 | 18.4 | 177.6 | 631.4 | 6.5 | 33.0 | 71.2 |
| 9MACCA | 42 | 2.14 | 0.371 | 2.66 | 0.67 | 0.589 | 0.333 | 22.5 | 213.7 | 802.1 | 8.7 | 32.5 | 109.1 |
| 9MAMCA | 43 | 1.97 | 0.232 | 2.94 | 0.55 | 0.340 | 0.189 | 36.1 | 164.5 | 400.3 | 10.7 | 53.1 | 95.2 |
| 9MIMCA | 44 | 2.97 | 0.265 | 3.55 | 1.19 | 0.662 | 0.207 | 25.0 | 1217.8 | 339.6 | 9.9 | 65.9 | 655.0 |
| 9MPHAU | 45 | 1.12 | 0.083 | 0.42 | 0.11 | 0.065 | 0.112 | 2.9 | 116.0 | 159.1 | 10.2 | 16.5 | 33.4 |
| 10MACCA | 46 | 2.24 | 0.396 | 2.86 | 0.83 | 0.617 | 0.338 | 24.9 | 260.5 | 676.6 | 15.3 | 38.5 | 152.4 |
| 10MIMCA | 47 | 2.88 | 0.269 | 4.45 | 1.45 | 0.751 | 0.190 | 22.4 | 155.3 | 152.6 | 6.9 | 82.1 | 89.4 |
| 10MMISC | 48 | 3.16 | 0.178 | 3.30 | 1.27 | 0.611 | 0.245 | 34.3 | 108.0 | 167.6 | 8.1 | 32.5 | 36.9 |
| 10MPHAU | 49 | 1.50 | 0.102 | 0.58 | 0.13 | 0.091 | 0.134 | 9.6 | 76.0 | 247.4 | 9.9 | 15.6 | 20.3 |
| 10MPOAR | 50 | 3.33 | 0.298 | 2.55 | 0.74 | 0.793 | 0.221 | 57.5 | 115.0 | 1292.9 | 7.3 | 110.6 | 52.4 |
| 11MACCA | 51 | 2.20 | 0.368 | 2.83 | 0.73 | 0.578 | 0.339 | 22.9 | 154.5 | 956.2 | 7.0 | 26.3 | 56.4 |
| 11MIMCA | 52 | 2.16 | 0.251 | 4.26 | 1.14 | 0.530 | 0.164 | 20.7 | 176.9 | 222.8 | 4.9 | 49.4 | 90.3 |
| 11MPEVI | 53 | 3.27 | 0.606 | 6.15 | 1.40 | 0.319 | 0.263 | 64.4 | 160.9 | 777.8 | 22.6 | 57.7 | 92.6 |
| 11MPHAU | 54 | 0.99 | 0.092 | 0.68 | 0.12 | 0.058 | 0.105 | 2.9 | 67.4 | 156.9 | 12.4 | 17.3 | 10.9 |
| 11MPOAR | 55 | 2.20 | 0.338 | 3.49 | 0.58 | 0.744 | 0.184 | 26.8 | 211.6 | 1412.9 | 4.6 | 50.2 | 42.1 |
| 12MACCA | 56 | 2.34 | 0.284 | 2.72 | 0.72 | 0.557 | 0.293 | 26.0 | 114.7 | 576.4 | 5.6 | 28.0 | 64.9 |
| 12MIMCA | 57 | 2.76 | 0.279 | 3.78 | 1.29 | 0.717 | 0.221 | 24.7 | 100.1 | 152.1 | 6.4 | 76.1 | 51.7 |
| 12MPEVI | 58 | 3.42 | 0.385 | 3.83 | 1.03 | 0.246 | 0.246 | 42.2 | 127.9 | 838.3 | 2.4 | 66.9 | 42.7 |
| 12MPHAU | 59 | 1.46 | 0.108 | 0.71 | 0.15 | 0.079 | 0.138 | 3.8 | 70.7 | 252.2 | 12.9 | 18.7 | 1.7 |
| 13MACCA | 60 | 1.97 | 0.310 | 2.37 | 0.74 | 0.572 | 0.280 | 19.0 | 272.6 | 1185.2 | 9.4 | 24.6 | 136.8 |
| 13MHIMO | 61 | 1.92 | 0.188 | 1.34 | 1.24 | 0.670 | 0.170 | 28.8 | 135.9 | 609.6 | 2.9 | 34.1 | 52.9 |
| 13MIMCA | 62 | 1.92 | 0.150 | 3.03 | 1.09 | 0.503 | 0.142 | 24.8 | 96.8 | 234.4 | 2.6 | 39.6 | 49.3 |
| 13MPEVI | 63 | 3.57 | 0.390 | 3.48 | 1.26 | 0.307 | 0.306 | 42.2 | 415.9 | 780.8 | 4.2 | 48.7 | 242.7 |
| 13MPHAU | 64 | 1.58 | 0.117 | 0.65 | 0.15 | 0.106 | 0.137 | 4.6 | 118.5 | 238.0 | 19.3 | 19.2 | 19.6 |
| 13MPOAR | 65 | 2.42 | 0.295 | 2.02 | 0.75 | 0.780 | 0.209 | 25.0 | 283.5 | 2340.2 | 4.0 | 58.2 | 116.4 |
| 14MACCA | 66 | 1.97 | 0.293 | 2.83 | 0.65 | 0.496 | 0.326 | 21.7 | 225.7 | 616.3 | 7.3 | 20.6 | 147.6 |
| 14MPEVI | 67 | 2.60 | 0.499 | 4.70 | 1.46 | 0.286 | 0.287 | 43.7 | 718.5 | 976.9 | 38.2 | 54.6 | 449.0 |
| 14MPHAU | 68 | 1.32 | 0.096 | 0.67 | 0.13 | 0.094 | 0.144 | 3.6 | 88.3 | 122.5 | 23.1 | 19.9 | 30.2 |
| 14MPOAR | 69 | 3.16 | 0.316 | 2.20 | 0.78 | 0.772 | 0.254 | 21.1 | 656.4 | 1881.7 | 23.6 | 73.7 | 315.5 |
| 14MSCFL | 70 | 1.61 | 0.283 | 1.62 | 0.19 | 0.168 | 0.185 | 6.4 | 121.4 | 588.1 | 34.1 | 31.9 | 35.5 |
| 15MACCA | 71 | 2.02 | 0.310 | 2.52 | 0.73 | 0.498 | 0.278 | 19.2 | 258.1 | 1146.3 | 10.0 | 27.2 | 152.5 |
| 15MCASE | 72 | 2.84 | 0.225 | 2.17 | 1.46 | 0.411 | 0.386 | 26.9 | 234.4 | 535.5 | 3.9 | 37.6 | 118.1 |
| 15MPHAU | 73 | 1.09 | 0.103 | 0.74 | 0.15 | 0.101 | 0.119 | 3.8 | 131.2 | 209.5 | 18.9 | 18.7 | 50.5 |
| 15MSCFL | 74 | 1.33 | 0.265 | 1.40 | 0.18 | 0.142 | 0.146 | 7.7 | 113.4 | 889.5 | 45.6 | 36.8 | 37.1 |
| 15MTYSP | 75 | 1.93 | 0.152 | 0.42 | 0.88 | 0.388 | 0.218 | 35.3 | 948.4 | 1199.2 | 10.6 | 29.0 | 780.0 |

**Table D23. Leaf nutrient data for the six species most present at each plot at the *Phragmites*-absent site**

| Description | Lab # | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | B (ppm) | Fe (ppm) | Mn (ppm) | Cu (ppm) | Zn (ppm) | Al (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1DACCA | 1 | 2.84 | 0.277 | 2.15 | 0.59 | 0.493 | 0.606 | 21.7 | 977.1 | 597.8 | 3.8 | 37.5 | 472.3 |
| 1DHIMO | 2 | 0.98 | 0.225 | 1.45 | 0.45 | 0.471 | 0.142 | 17.3 | 754.1 | 284.2 | 6.4 | 33.3 | 485.0 |
| 1DIMCA | 3 | 1.33 | 0.171 | 3.97 | 1.02 | 0.504 | 0.138 | 22.6 | 841.6 | 249.5 | 5.6 | 49.3 | 460.1 |
| 1DPEVI | 4 | 2.15 | 0.510 | 5.45 | 1.38 | 0.279 | 0.193 | 40.3 | 2117.5 | 974.8 | 6.8 | 50.8 | 1149.9 |
| 1DPOAR | 5 | 1.43 | 0.253 | 2.49 | 0.76 | 0.749 | 0.226 | 24.8 | 2807.7 | 1056.6 | 8.1 | 62.0 | 1861.3 |
| 2DCUGR | 6 | 2.08 | 0.350 | 3.25 | 0.35 | 0.262 | 0.198 | 16.4 | 314.7 | 371.7 | 3.9 | 42.1 | 146.4 |
| 2DIMCA | 7 | 1.82 | 0.219 | 3.60 | 1.02 | 0.390 | 0.154 | 19.8 | 192.1 | 162.1 | 3.2 | 51.6 | 121.4 |
| 2DPEVI | 8 | 2.62 | 0.493 | 5.20 | 1.30 | 0.329 | 0.253 | 39.6 | 1025.5 | 1073.6 | 7.2 | 62.4 | 546.7 |
| 2DPOAR | 9 | 1.89 | 0.263 | 2.98 | 0.68 | 0.768 | 0.204 | 24.8 | 398.9 | 1187.5 | 3.9 | 57.5 | 210.3 |
| 2DTYSP | 10 | 0.90 | 0.095 | 0.62 | 0.35 | 0.307 | 0.163 | 9.3 | 170.4 | 809.6 | 1.0 | 12.5 | 74.1 |
| 3DCIAR | 11 | 1.03 | 0.121 | 1.52 | 0.16 | 0.116 | 0.117 | 6.3 | 313.5 | 134.3 | 3.8 | 24.5 | 77.8 |
| 3DIMCA | 12 | 1.54 | 0.238 | 3.16 | 1.09 | 0.433 | 0.166 | 22.5 | 160.1 | 183.7 | 3.0 | 46.0 | 105.5 |
| 3DPEVI | 13 | 2.32 | 0.512 | 4.93 | 1.27 | 0.325 | 0.221 | 89.5 | 620.9 | 805.9 | 6.6 | 56.8 | 616.8 |
| 3DP0AR | 14 | 1.06 | 0.269 | 2.94 | 0.60 | 0.659 | 0.146 | 25.0 | 296.4 | 1151.1 | 2.1 | 42.0 | 114.5 |
| 3DTYSP | 15 | 0.83 | 0.123 | 1.07 | 0.41 | 0.331 | 0.155 | 10.3 | 157.0 | 717.1 | 1.3 | 14.0 | 49.7 |
| 4DCUGR | 16 | 1.56 | 0.286 | 2.38 | 0.24 | 0.120 | 0.148 | 14.3 | 113.6 | 71.4 | 2.2 | 21.3 | 52.2 |
| 4DIMCA | 17 | 1.45 | 0.229 | 3.44 | 1.03 | 0.423 | 0.188 | 25.0 | 423.6 | 244.5 | 3.8 | 43.7 | 171.5 |
| 4DPEVI | 18 | 3.51 | 0.544 | 5.49 | 1.66 | 0.379 | 0.375 | 50.7 | 1584.2 | 1066.2 | 6.2 | 66.3 | 697.1 |
| 4DPOAR | 19 | 1.34 | 0.263 | 2.22 | 0.59 | 0.588 | 0.174 | 23.8 | 831.0 | 1159.9 | 2.5 | 41.9 | 354.5 |
| 4DTYSP | 20 | 1.25 | 0.155 | 1.16 | 0.40 | 0.375 | 0.154 | 10.4 | 429.3 | 464.2 | 4.4 | 19.4 | 221.6 |
| 5DACCA | 21 | 1.53 | 0.315 | 2.86 | 0.63 | 0.431 | 0.451 | 16.7 | 674.7 | 971.6 | 11.2 | 33.1 | 326.1 |
| 5DHIMO | 22 | 2.64 | 0.360 | 2.27 | 1.13 | 0.614 | 0.253 | 43.0 | 266.7 | 475.0 | 81.1 | 41.8 | 85.2 |
| 5DPEVI | 23 | 2.73 | 0.574 | 5.45 | 1.05 | 0.309 | 0.278 | 38.4 | 521.0 | 532.9 | 4.9 | 48.9 | 333.1 |
| 5DPOAR | 24 | 1.35 | 0.259 | 2.77 | 0.66 | 0.735 | 0.174 | 25.0 | 231.9 | 1592.5 | 3.4 | 74.3 | 131.9 |
| 5DZIAQ | 25 | 1.49 | 0.294 | 2.07 | 0.33 | 0.168 | 0.174 | 10.2 | 170.1 | 396.8 | 514.5 | 39.2 | 100.6 |
| 6DIMCA | 26 | 1.96 | 0.277 | 3.19 | 1.03 | 0.475 | 0.227 | 22.1 | 273.3 | 454.0 | 8.7 | 47.3 | 133.1 |
| 6DPEVI | 27 | 3.72 | 0.538 | 3.94 | 1.65 | 0.438 | 0.402 | 60.0 | 527.9 | 1504.9 | 6.4 | 62.2 | 338.9 |
| 6DPOAR | 28 | 1.35 | 0.224 | 2.45 | 0.68 | 0.702 | 0.179 | 22.9 | 301.1 | 1436.2 | 2.5 | 52.3 | 164.5 |
| 6DTYSP | 29 | 0.81 | 0.075 | 0.54 | 0.50 | 0.409 | 0.189 | 10.7 | 139.5 | 430.6 | 1.7 | 16.4 | 65.7 |
| 7DHIMO | 30 | 1.52 | 0.331 | 4.09 | 0.67 | 0.246 | 0.186 | 35.3 | 428.7 | 332.0 | 5.5 | 41.4 | 208.0 |
| 7DIMCA | 31 | 1.24 | 0.242 | 3.65 | 1.11 | 0.549 | 0.200 | 27.6 | 368.2 | 323.5 | 4.3 | 48.2 | 174.5 |
| 7DPEVI | 32 | 3.07 | 0.436 | 4.13 | 0.97 | 0.322 | 0.276 | 40.0 | 916.8 | 843.4 | 2.1 | 51.6 | 487.3 |
| 7DPOAR | 33 | 1.12 | 0.185 | 2.59 | 0.61 | 0.619 | 0.141 | 20.3 | 564.2 | 977.8 | 3.3 | 40.1 | 230.6 |
| 7DTYSP | 34 | 1.25 | 0.159 | 1.42 | 0.47 | 0.372 | 0.204 | 17.3 | 961.0 | 669.9 | 6.4 | 24.6 | 462.1 |

**Table D23 continued**

| Description | Lab # | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | B (ppm) | Fe (ppm) | Mn (ppm) | Cu (ppm) | Zn (ppm) | Al (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8DBILA | 35 | 1.36 | 0.258 | 2.74 | 1.89 | 0.348 | 0.376 | 31.9 | 118.6 | 518.5 | 7.3 | 43.6 | 47.9 |
| 8DHIMO | 36 | 1.66 | 0.255 | 1.46 | 0.77 | 0.522 | 0.158 | 21.5 | 123.5 | 278.1 | 4.2 | 32.8 | 60.9 |
| 8DIMCA | 37 | 1.76 | 0.238 | 4.03 | 1.12 | 0.462 | 0.210 | 23.0 | 240.4 | 155.9 | 4.4 | 55.4 | 131.2 |
| 8DPEVI | 38 | 4.00 | 0.840 | 6.54 | 1.33 | 0.425 | 0.412 | 51.4 | 330.5 | 789.7 | 10.3 | 74.6 | 166.6 |
| 8DPOAR | 39 | 2.01 | 0.331 | 2.65 | 0.73 | 0.776 | 0.238 | 25.0 | 728.1 | 1164.7 | 5.0 | 81.2 | 468.4 |
| 9DIMCA | 40 | 1.35 | 0.192 | 3.23 | 1.17 | 0.686 | 0.183 | 34.2 | 635.3 | 511.4 | 9.0 | 66.5 | 278.5 |
| 9DPEVI | 41 | 3.55 | 0.485 | 4.79 | 1.18 | 0.406 | 0.420 | 38.4 | 2840.9 | 1125.8 | 7.6 | 90.4 | 1578.7 |
| 9DPOAR | 42 | 1.68 | 0.264 | 3.18 | 0.79 | 0.806 | 0.246 | 25.5 | 1283.4 | 1368.2 | 4.4 | 57.9 | 656.8 |
| 9DSCTA | 43 | 1.93 | 0.248 | 2.72 | 0.90 | 0.590 | 0.418 | 28.6 | 252.1 | 1109.5 | 5.3 | 56.4 | 94.6 |
| 9DTYSP | 44 | 1.13 | 0.194 | 1.89 | 0.25 | 0.195 | 0.182 | 8.6 | 485.8 | 276.8 | 23.2 | 30.9 | 254.9 |
| 10DIMCA | 45 | 1.09 | 0.183 | 2.63 | 0.84 | 0.367 | 0.155 | 13.2 | 267.5 | 233.1 | 5.4 | 38.0 | 92.9 |
| 10DPEVI | 46 | 2.82 | 0.624 | 5.42 | 1.09 | 0.355 | 0.330 | 37.4 | 1133.5 | 628.7 | 3.3 | 56.5 | 432.4 |
| 10DPOAR | 47 | 1.64 | 0.275 | 2.41 | 0.76 | 0.654 | 0.191 | 22.2 | 791.8 | 1537.6 | 3.0 | 116.1 | 313.9 |
| 10DSPEU | 48 | 1.26 | 0.214 | 2.36 | 0.47 | 0.449 | 0.591 | 15.4 | 828.1 | 521.6 | 3.0 | 22.6 | 303.8 |
| 10DTYSP | 49 | 1.07 | 0.125 | 0.78 | 0.50 | 0.335 | 0.164 | 31.9 | 339.8 | 504.8 | 2.6 | 17.7 | 324.9 |
| 11DCUGR | 50 | 2.49 | 0.327 | 3.09 | 0.31 | 0.315 | 0.208 | 25.0 | 158.4 | 576.3 | 1.7 | 34.5 | 111.3 |
| 11DPEVI | 51 | 3.10 | 0.410 | 4.47 | 1.44 | 0.333 | 0.332 | 50.4 | 855.1 | 1706.9 | 4.8 | 54.4 | 416.3 |
| 11DPOAR | 52 | 1.54 | 0.193 | 2.62 | 0.66 | 0.830 | 0.188 | 23.8 | 212.9 | 1598.7 | 1.3 | 43.9 | 77.8 |
| 11DSCTA | 53 | 1.22 | 0.220 | 1.85 | 0.44 | 0.287 | 0.427 | 9.6 | 180.8 | 560.0 | 28.9 | 33.9 | 73.6 |
| 11DSISU | 54 | 1.92 | 0.285 | 1.85 | 0.86 | 0.301 | 0.275 | 43.8 | 91.2 | 219.5 | 3.0 | 47.1 | 27.7 |
| 11DTYSP | 55 | 0.60 | 0.128 | 1.18 | 0.49 | 0.386 | 0.197 | 11.1 | 105.9 | 532.8 | 6.9 | 17.7 | 55.7 |
| 12DIMCA | 56 | 1.84 | 0.167 | 3.75 | 1.26 | 0.486 | 0.177 | 33.9 | 554.2 | 273.8 | 4.6 | 57.7 | 412.3 |
| 12DPEVI | 57 | 3.42 | 0.608 | 6.16 | 1.62 | 0.389 | 0.364 | 61.4 | 3385.5 | 1176.6 | 7.8 | 83.4 | 2202.3 |
| 12DPOAR | 58 | 1.71 | 0.245 | 2.89 | 0.65 | 0.734 | 0.202 | 23.0 | 1692.0 | 1137.7 | 30.8 | 60.2 | 1233.7 |
| 12DTYSP | 59 | 1.41 | 0.215 | 2.25 | 0.57 | 0.355 | 0.166 | 19.1 | 1124.5 | 969.8 | 3.8 | 25.8 | 689.6 |
| 12DZIAQ | 60 | 1.89 | 0.194 | 2.11 | 0.23 | 0.098 | 0.168 | 7.3 | 322.5 | 148.6 | 11.4 | 20.7 | 164.8 |
| 13DIMCA | 61 | 1.67 | 0.189 | 3.52 | 1.17 | 0.455 | 0.232 | 65.2 | 179.3 | 205.7 | 4.3 | 52.4 | 197.2 |
| 13DPEVI | 62 | 3.59 | 0.515 | 5.13 | 1.67 | 0.381 | 0.394 | 66.5 | 651.5 | 1286.3 | 3.8 | 66.7 | 413.7 |
| 13DPOAR | 63 | 1.35 | 0.190 | 2.37 | 0.65 | 0.742 | 0.195 | 26.8 | 267.5 | 1222.8 | 2.2 | 55.5 | 122.6 |
| 13DSPEU | 64 | 1.36 | 0.127 | 1.44 | 0.49 | 0.534 | 0.284 | 52.5 | 295.4 | 632.8 | 1.7 | 19.2 | 363.7 |
| 13DTYSP | 65 | 0.87 | 0.087 | 0.62 | 0.34 | 0.325 | 0.151 | 13.9 | 191.0 | 442.9 | 1.7 | 11.9 | 109.6 |
| 14DIMCA | 66 | 1.71 | 0.187 | 3.85 | 1.49 | 0.533 | 0.172 | 39.8 | 395.7 | 371.1 | 78.0 | 56.1 | 203.7 |
| 14DNULU | 67 | 1.24 | 0.225 | 2.43 | 0.54 | 0.128 | 0.146 | 28.4 | 328.8 | 326.0 | 2.6 | 16.0 | 159.3 |
| 14DPEVI | 68 | 3.51 | 0.621 | 5.66 | 1.78 | 0.352 | 0.340 | 75.9 | 1705.8 | 857.4 | 8.4 | 71.3 | 1079.6 |
| 14DPOAR | 69 | 1.85 | 0.296 | 3.23 | 0.77 | 0.619 | 0.183 | 22.8 | 766.9 | 1848.5 | 5.6 | 70.1 | 367.4 |
| 14DTYSP | 70 | 0.91 | 0.117 | 0.86 | 0.41 | 0.329 | 0.106 | 8.4 | 272.4 | 789.1 | 1.2 | 13.4 | 69.9 |
| 15DPEVI | 71 | 3.40 | 0.606 | 6.08 | 1.56 | 0.405 | 0.375 | 67.1 | 5967.3 | 1152.0 | 10.7 | 166.9 | 2761.2 |
| 15DPOAR | 72 | 1.92 | 0.306 | 3.21 | 0.78 | 0.746 | 0.219 | 26.2 | 1815.3 | 1795.2 | 7.7 | 69.4 | 1012.7 |
| 15DSALA | 73 | 1.75 | 0.385 | 4.17 | 0.63 | 0.428 | 0.181 | 28.8 | 2094.6 | 737.1 | 6.9 | 44.9 | 1386.0 |
| 15DTYSP | 74 | 1.25 | 0.178 | 2.40 | 0.42 | 0.231 | 0.121 | 11.5 | 1096.2 | 485.3 | 16.6 | 25.9 | 725.5 |
| 15DZIAQ | 75 | 1.76 | 0.245 | 3.77 | 0.25 | 0.154 | 0.166 | 7.7 | 786.9 | 280.8 | 9.0 | 29.0 | 447.2 |

**Table D24. Biomass data (g) for each species at each 1m$^2$ plot at the *Phragmites*-dominant site. X = species absent.**

| Plot Number | 1M | 2M | 3M | 4M | 5M | 6M | 7M | 8M | 9M | 10M | 11M | 12M | 13M | 14M | 15M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCA | 189.9 | 40.3 | X | 15 | 8 | 85.2 | 132.8 | X | 49.4 | 44.9 | 51 | 42.5 | 136.9 | 142.8 | 159.7 |
| AMCA | X | X | 9 | X | X | X | X | X | 64.4 | X | X | X | X | X | X |
| APAM | X | X | 4.4 | 2 | 168 | X | X | 30 | X | X | X | X | X | X | X |
| BILA | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| BOCY | X | X | 24.9 | 3.1 | X | 14.1 | X | X | X | X | X | X | X | X | X |
| CASE | X | X | 174.8 | 17.1 | 87.9 | 18.6 | X | X | X | X | X | X | X | X | 3.9 |
| CIAR | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| CUGR | X | X | 6.3 | 3.9 | X | X | X | X | X | 0.8 | X | X | 3.9 | X | X |
| ELOB | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| HIMO | 46.7 | X | X | X | X | X | X | X | X | X | X | X | 23.4 | X | X |
| IMCA | 26.2 | 17.3 | 117.3 | 43.2 | 46.4 | 124.6 | 6.8 | 4.3 | 18.3 | 85.5 | 55.3 | 154.5 | 38.9 | X | 2.7 |
| LEOR | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| MEAR | X | X | 24.4 | X | X | X | X | X | X | X | X | X | X | X | X |
| MISC | X | X | X | X | X | X | 0.1 | X | X | 9.7 | X | X | X | 0.8 | X |
| NULU | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| PEVI | 33.9 | 60.4 | 4.6 | X | 12.7 | 21.8 | 19.8 | X | 0.1 | 2.8 | 3.9 | 12 | 22.9 | 142 | 3 |
| PHAU | 1149.9 | 1070.3 | 107.4 | 1672.2 | 1610.3 | 885.6 | 1100.4 | 1616.3 | 2140.5 | 1310.7 | 1629.9 | 1786.6 | 970.8 | 930.5 | 211.8 |
| POAR | 22.3 | 7.8 | 9.2 | X | X | 13.4 | X | 3.1 | X | 6.9 | 77.4 | X | 46.7 | 9.6 | X |
| SALA | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| SCFL | X | 85 | 20.7 | X | 30.1 | 21.1 | X | X | X | X | X | X | X | 56.5 | 157.3 |
| SCTA | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| SISU | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| SPEU | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| TYSP | 46.9 | 40.1 | X | X | X | X | X | 2.7 | X | X | X | X | X | X | 14.1 |
| ZIAQ | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Total Biomass | 1515.8 | 1321.2 | 503 | 1756.5 | 1963.4 | 1184.4 | 1259.9 | 1656.4 | 2272.7 | 1461.3 | 1817.5 | 1995.6 | 1243.5 | 1282.2 | 552.5 |

**Table D25. Biomass data (g) for each species at each 1m$^2$ plot at the *Phragmites*-absent site. X = species absent.**

| Plot number | 1D | 2D | 3D | 4D | 5D | 6D | 7D | 8D | 9D | 10D | 11D | 12D | 13D | 14D | 15D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCA | 4.9 | X | X | X | 35.4 | X | X | X | X | X | X | X | 3.7 | X | X |
| AMCA | X | X | X | X | X | X | X | X | X | X | X | 0.1 | X | X | X |
| APAM | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| BILA | X | X | X | X | X | X | X | 84.7 | X | X | X | X | X | X | X |
| BOCY | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| CASE | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| CIAR | X | X | 6.4 | X | X | X | X | X | X | 4.3 | X | X | X | X | X |
| CUGR | X | 4.2 | X | 3.1 | X | X | X | 0.01 | X | 0.1 | 58.5 | X | 1.3 | X | 0.01 |
| ELOB | X | X | X | X | X | X | X | X | X | 15.8 | X | X | X | X | X |
| HIMO | 21.2 | X | X | X | 10.9 | X | 7.5 | 62.1 | X | X | X | X | X | X | X |
| IMCA | 49.2 | 118.3 | 54.8 | 40.7 | X | 2.9 | 19.3 | 226.4 | 22.3 | 27.8 | 13.7 | 72.5 | 90.3 | 27.2 | X |
| LEOR | X | X | X | 1.5 | X | X | X | X | X | 0.1 | X | X | X | X | X |
| MEAR | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| MISC | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| NULU | X | X | X | X | X | X | X | X | X | X | X | X | X | 38.7 | X |
| PEVI | 148.7 | 87.7 | 28.2 | 75.5 | 51.4 | 17.7 | 28.5 | 29.8 | 64.8 | 58.1 | 40.8 | 90.5 | 101.2 | 63 | 53.3 |
| PHAU | X | X | 1.3 | X | X | X | X | X | X | X | X | X | X | X | X |
| POAR | 80.8 | 98.6 | 165.5 | 70.6 | 372.8 | 370.2 | 247.5 | 88.8 | 254.7 | 412.4 | 206.7 | 127.9 | 313.8 | 106.6 | 115.2 |
| SALA | X | X | X | X | X | X | X | 6.5 | X | X | X | X | X | X | 19.7 |
| SCFL | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| SCTA | X | X | X | X | X | X | X | X | 7.2 | X | 111.8 | X | X | X | X |
| SISU | X | X | X | X | X | X | X | X | X | 0.2 | 19.5 | X | X | X | X |
| SPEU | X | X | X | X | X | X | X | X | X | 44.9 | X | X | 55 | X | X |
| TYSP | X | 128.2 | 69.9 | 46.8 | X | 234.7 | 31 | X | 22.9 | 225.2 | 166.8 | 2.2 | 131.4 | 21.8 | 5 |
| ZIAQ | X | X | X | X | 12.1 | 0.3 | X | 2.8 | 3.9 | X | X | 4.4 | X | X | 1.6 |
| Total Biomass | 304.8 | 437 | 326.1 | 238.2 | 482.6 | 625.8 | 333.8 | 501.11 | 375.8 | 788.9 | 617.8 | 297.6 | 696.7 | 257.3 | 194.81 |

**Table D26. Elevation (cm) of marsh plots above base of data-logging well (see A. Baldwin, unpublished data) located on tidal creek equidistant from each marsh site.**

| Plot | cm | ft |
|---|---|---|
| 1D001 | 15.5 | 0.51 |
| 2D101 | 21.9 | 0.72 |
| 3D002 | 18.3 | 0.6 |
| 4D111 | 20.4 | 0.67 |
| 5D112 | 8.2 | 0.27 |
| 6D201 | 18.3 | 0.6 |
| 7D102 | 18.0 | 0.59 |
| 8D221 | 18.9 | 0.62 |
| 9D202 | 14.9 | 0.49 |
| 10D203 | 18.6 | 0.61 |
| 11D222 | 14.6 | 0.48 |
| 12D103 | 12.8 | 0.42 |
| 13D223 | 17.4 | 0.57 |
| 14D113 | 15.8 | 0.52 |
| 15D003 | 8.5 | 0.28 |
| 1M221 | 18.3 | 0.6 |
| 2M201 | 18.9 | 0.62 |
| 3M101 | 32.9 | 1.08 |
| 4M001 | 33.2 | 1.09 |
| 5M111 | 29.0 | 0.95 |
| 6M222 | 29.3 | 0.96 |
| 7M102 | 26.2 | 0.86 |
| 8M113 | 35.4 | 1.16 |
| 9M103 | 30.8 | 1.01 |
| 10M203 | 29.0 | 0.95 |
| 11M002 | 21.6 | 0.71 |
| 12M223 | 23.2 | 0.76 |
| 13M202 | 18.9 | 0.62 |
| 14M112 | 2.4 | 0.08 |
| 15M003 | 16.5 | 0.54 |

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