## ABSTRACT

James H. Taylor. THE EFFECTS OF ALTERED INUNDATION AND WRACK DEPOSITION ON NITRIFICATION, DENITRIFICATION, AND THE STANDING STOCKS OF $NO_3^-$ AND $NO_2^-$. (Under the direction of Robert R. Christian, Ph.D.) Department of Biology, August 1995.

Concentrations of groundwater ammonium, nitrate, nitrite, and gaseous nitrous oxide were measured to estimate nitrification and denitrification rates and to determine how altered inundation and wrack deposition affected nitrogen cycling. Three blocks (Blocks 1-3) were established at the junction of a vegetative patch of *Juncus roemerianus* and a community dominated by both *Spartina patens* and *Distichlis spicata*. Each block contained three plots that received a different inundation treatment: (1) Flooded (**F**), a plot receiving water pumped from the tidal creek and surrounded by a border to help retain the pumped water; (2) Border Control (**BC**), a plot surrounded by a border; and (3) Control (**C**), a plot delineated by four pieces of 3-foot PVC; one in each corner. Each plot (**F**, **BC**, and **C**) was divided in half, and each half received a different vegetative treatment: (1) Wrack (**W**), the half of the vegetated plot covered by wrack; and (2) Vegetation (**V**), the vegetated half of the plot.

Fifteen cores were taken from each vegetative treatment, and the acetylene inhibition technique was used to estimate nitrification and denitrification rates. Nitrification rates were obtained by measuring the changes in the concentrations of (1) $NO_3^-$ and (2) $NO_2^-$ after a six hour incubation period with and without acetylene. Nitrate and nitrite concentrations and nitrification rates were measured during June, August, and September. Denitrification rates were obtained for August and September. In October, similar techniques were used to determine if short-term changes in the moisture of the soil affected the rates of nitrification or denitrification.

The rates of nitrification and denitrification obtained during the experiment were within the range of 0 to 30 µmol $m^{-2}$ $h^{-1}$ and agreed with previously published data. Altered inundation patterns did not affect nitrification or denitrification rates. Nitrogen cycling in tidal salt-marsh soils appear relatively insensitive to changes in flooding regimes since the biota of the system have adapted to live in areas that experience rapid changes in flooding conditions—tides, storm surges, flooding events cause by rainfall, among others.

Wrack deposition affected nitrification and denitrification rates. Although the acetylene based method used in the study detected increased nitrification rates only during September, wrack is hypothesized to increase nitrification rates. Denitrification rates were much higher where wrack deposition occurred. I propose wrack provides labile carbon required by denitrifying organisms.

In conclusion, flooding conditions may stress soil ecosystems but should not affect processes occurring in tidally influenced salt-marshes if those systems are exposed to sudden changes in the flooding conditions—storm surges, rainfall, flooding, and tides—on a routine basis. However, the disturbance event of wrack deposition may affect bio-geochemical processes—nitrificaion and denitrification—since the biotic and abiotic factors controlling the cycling are more directly impacted by the die-off of vegetation.

# THE EFFECTS OF ALTERED INUNDATION AND WRACK DEPOSITION ON NITRIFICATION, DENITRIFICATION, AND THE STANDING STOCKS OF $NO_3^-$ AND $NO_2^-$.

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by

James Harvey Taylor III

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# THE EFFECTS OF ALTERED INUNDATION AND WRACK DEPOSITION ON NITRIFICATION, DENITRIFICATION, AND THE STANDING STOCKS OF $NO_3^-$ AND $NO_2^-$.

by

James Harvey Taylor III

APPROVED BY:

THESIS DIRECTOR ______________________________

Robert R. Christian, Ph.D.

COMMITTEE MEMBER ______________________________

Iris C. Anderson, Ph.D.

COMMITTEE MEMBER ______________________________

Mark M. Brinson, Ph.D.

COMMITTEE MEMBER ______________________________

Donald Holbert, Ph.D.

COMMITTEE MEMBER ______________________________

Donald W. Stanley, Ph.D.

CHAIR OF THE
DEPARTMENT OF
BIOLOGY ______________________________

Charles E. Bland, Ph.D.

DEAN OF THE
GRADUATE SCHOOL ______________________________

Thomas L. Feldbush, Ph.D.

"By knowing things that exist, you can know that which does not exist."

-Miyamoto Musashi

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| | |
|---|---|
| A | Acetylene |
| **BC** | Border Control |
| **C** | Control |
| cm | Centimeter |
| d | Day |
| DNRA | Dissimilatory Nitrate Reduction to Ammonia |
| **F** | Flooded |
| h | Hour |
| **J** | *Juncus roemerianus* |
| LTER | Long Term Ecological Research |
| m | Meter |
| M | Moles |
| µ | micro- |
| n | nano- |
| N | Nitrogen |
| $^{15}N$ | labeled Nitrogen |
| $N_2$ | Dinitrogen |
| $NH_4$ | Ammonia |
| NO | Nitric oxide |
| $NO_2$ | Nitrite |
| $NO_3$ | Nitrate |
| $N_2O$ | Nitrous Oxide |
| ROL | Radial Oxygen Loss |

| | |
|---|---|
| T0 | Indicates a zero hour incubation |
| T1 | One hour incubation |
| T6 | Six hour incubation |
| V | Volt |
| VCR | Virginia Coastal Reserve |
| **W** | Wrack |

# Introduction

Sea level rise affects the rates of denitrification and nitrification in salt marshes by changing the environmental conditions that influence the two processes. Increased flooding affects the salinity and supply of oxygen in salt marshes (Bertness, 1991). Flooding keeps creekside salinities low while helping to create high saline conditions in marsh interiors (Blum, 1993). Furthermore, rising sea level changes the inundation of the marsh surface which in turn affects the growth and species composition of the vegetation (Bertness, 1991).

This study examines how denitrification and nitrification rates vary with changing environmental conditions. Increased inundation and *Spartina alterniflora*-wrack were added to the marsh surface to see how they affect nitrification and denitrification rates. Redox potentials, bulk densities, percentages of water, and concentrations of $NO_3^-$, $NO_2^-$, and $NH_4^+$ were also measured to indicate if changes in the system were occurring and to aid in the inference of the changes.

**<u>The Nitrogen Cycle</u>**:

The nitrogen cycle has been studied intensively in salt marshes since increases in nitrogen can (1) increase the standing biomass and productivity of marsh plants, (2) change the morphology—short to tall variety—of *Spartina alterniflora*, (3) increase the percentage of plants that carry seed, (4) alter abundances of plant species, (5) and increase the percent nitrogen in plant biomass (Valiela, 1983). The processes in the N-cycle—denitrification, nitrification, nitrogen fixation, etc—have been studied for many years, but some of the regulating factors of these processes are not fully understood (Atlas & Bartha, 1993). Similarly, measurements of the different processes within the nitrogen cycle have been hampered by the difficulty in measuring individual pathways without disturbing any of the others. Table 1 lists some of the forms of nitrogen in the nitrogen cycle, and Figure

1 illustrates the flows of different forms of nitrogen through the nitrogen cycle.

Table 1: Some of the nitrogen cycle's inorganic forms of nitrogen and their chemical formulas.

| Chemical Name | Chemical Formula | Chemical Name | Chemical Formula |
|---|---|---|---|
| Ammonia<br>Ammonium Ion<br>Nitrate<br>Nitrite | $NH_3$<br>$NH_4^+$<br>$NO_3^-$<br>$NO_2^-$ | Nitric Oxide<br>Nitrous Oxide<br>Dinitrogen | NO<br>$NO_2$<br>$N_2$ |

The nitrogen cycle may be considered as comprising five broad biological processes. Nitrogen fixation is the conversion of dinitrogen ($N_2$) to ammonium ($NH_4^+$) and then into organic nitrogen. The conversion of $NH_4^+$ to $NO_3^-$ with $NO_2^-$ as an obligate intermediary describes nitrification. Dissimilatory nitrate reduction to nitrite with further reduction comprises two processes. Denitrification produces gaseous nitrogen ($N_2$, $N_2O$, and NO) from the reduction of $NO_2^-$ through several steps. Dissimilatory nitrate reduction to ammonia (or ammonium) (DNRA) is the production of $NH_3$ from $NO_3^-$ where $NO_2^-$ is an obligate intermediate. Mineralization or ammonification is the process of producing $NH_4^+$ from organic compounds. Assimilation describes the uptake of $NH_4^+$, $NO_3^-$, and $NO_2^-$ by organisms.

**Nitrogen Fixation**

Nitrogen fixation converts dinitrogen to ammonium nitrogen. This pathway, which is inhibited by high oxygen partial pressure and $NH_4^+$ concentrations, occurs within anaerobic microsites for various aerobic bacteria, in anaerobic bacteria, and in some cyanobacteria (Atlas & Bartha, 1993).

**Nitrification**

Nitrification is the "biological oxidation of ammonia to nitrite and then nitrate"

(Christian & Day, 1989). Although some fungi and chemoheterotrophic microorganisms can nitrify, the main nitrifiers are chemoautotrophs that use reduced inorganic nitrogen as an energy source to fix inorganic carbon for growth (Christian & Day, 1989).

**Methods of measurement**

Acetylene has been used to inhibit nitrification in intact sediment cores (Sloth et al., 1992). Acetylene inhibition causes $NH_4^+$ concentrations to increase because $NH_4^+$ remains reduced instead of being oxidized through nitrification (Sloth et al., 1992). Concurrently, $NO_3^-$ and $NO_2^-$ concentrations decrease since their production by the nitrification process has been inhibited, whereas their consumption continues (McCarty & Bremner, 1986). The method subtracts the concentration of $NO_3^-$ and $NO_2^-$ changed over time in acetylene treated cores from the amount of change in untreated cores. The differences are the concentrations of $NO_3^-$ and $NO_2^-$ produced over the incubation period through nitrification. This method may be an accurate method when high concentrations of $NH_4$ are present or when nitrification is not linked to nitrogen fixation since acetylene also inhibits the production of $NH_4^+$ by the latter (Seitzinger & Garber, 1987). The use of the acetylene block technique would underestimate nitrification rates if nitrogen fixation is a significant source of $NH_4^+$.

Other methods have been used. Nitrapyrin (N-serve), another inhibitor of nitrification, is used in a similar fashion (Henriksen, 1980). McCarty and Bremner (1986) indicate that acetylene inhibition compares favorably to inhibition caused by N-serve and etridiazole. Methods using $^{14}CO_2$ oxidation in the presence and absence of N-serve have been used to estimate nitrification rates, but this method suffers since the conversion factors necessary to relate $^{14}CO_2$ fixation to $NH_4^+$ oxidation are not clearly known (Butler, 1988). Work using $^{15}N$ labeled $NH_4^+$ and $NO_3^-$ as tracers can measure minute changes in labeled nitrogen concentrations without inhibiting any of the nitrogen cycle

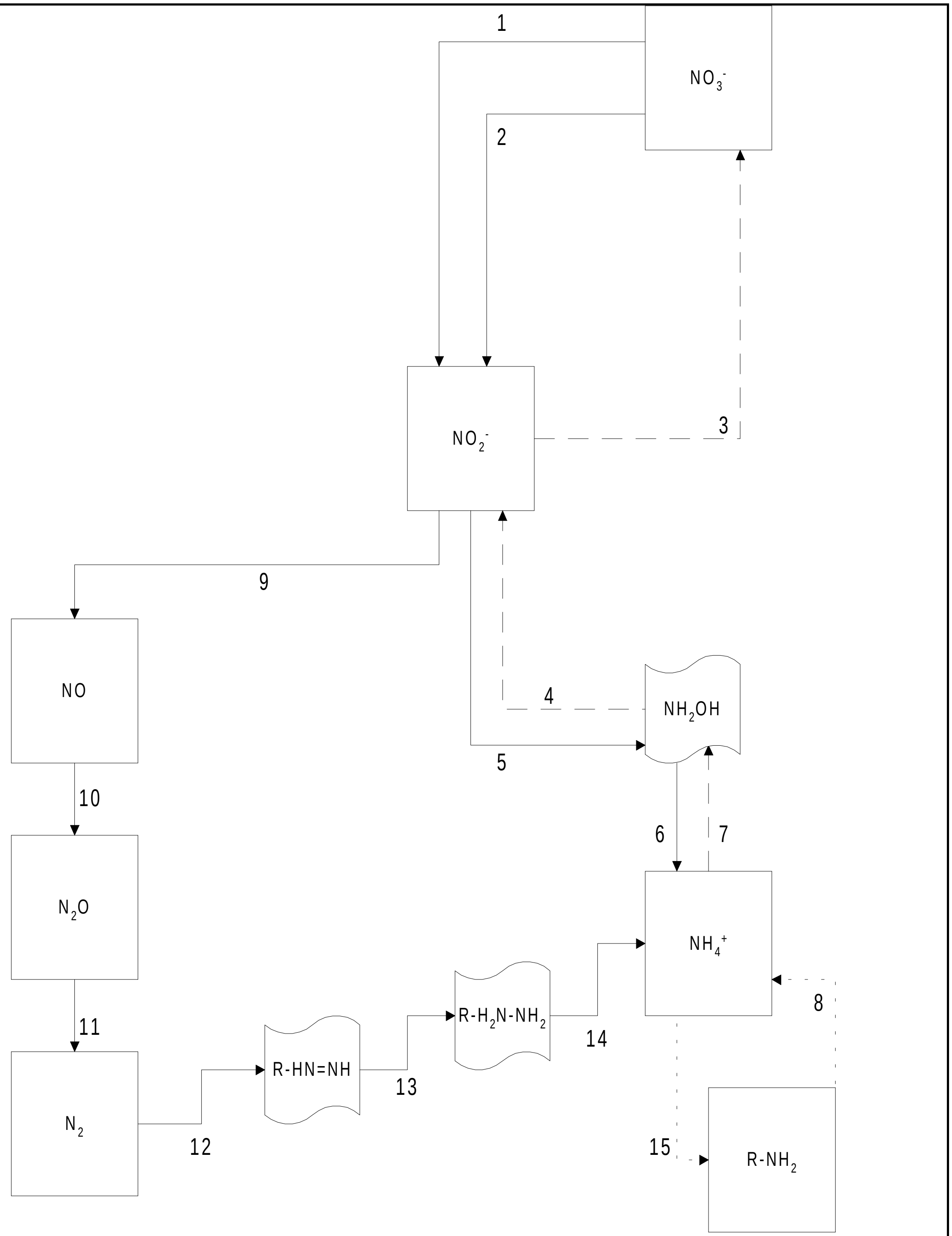



Figure 1: The processes in the N-cycle. N-fixation is steps 12, 13. and 14. Nitrification is steps 7, 4, and 3. Denitrification is steps 1, 9, 10, and 11. DNRA is steps 2, 5, and 6. Immobilization and assimilation of ammonium is step 15. Ammonification is step 8.

processes (Sloth et al., 1992). However, studies with $^{15}NH_4^+$ usually result in potential rather than in situ rates since $NH_4^+$ is usually added in concentrations much higher than ambient levels (Anderson, personal communication). Use of $^{15}NO_3^-$ isotope pool dilution techniques to measure nitrification removes this problem since the $NO_3^-$ added is the product of the process being measured (Anderson, personal communication).

**Nitrate Reduction**

Figure 1 also illustrates ways by which $NO_3^-$ is reduced—assimilatory nitrate reduction, dissimilatory $NO_3^-$ reduction to $NO_2^-$, denitrification, and DNRA. The reduction of nitrogen oxides produces up to six end-products that include nitrite, nitric oxide, nitrous oxide, dinitrogen, ammonia or ammonium. Occasionally an accumulation of $NH_2OH$ may occur. Denitrification generally occurs in bacteria that have oxidative metabolism, and DNRA occurs in bacteria with fermentative metabolism (Hattori, 1983). However, fermenters may also produce gaseous end products (Hattori, 1983).

**Assimilatory Reduction**

Assimilatory Nitrate Reduction involves the reduction of nitrogen oxides to ammonium as a prerequisite for their incorporation into biomass (Christian & Day, 1989).

**Denitrification**

Denitrification may be considered to involve up to four steps including the conversion of: (1) nitrate to nitrite; (2) nitrite to nitric oxide, NO; (3) nitric oxide to nitrous oxide, $N_2O$; and (4) nitrous oxide to dinitrogen. The end product of denitrification can be something other than dinitrogen. Nitric oxide or nitrous oxide can also be major products even though dinitrogen produces more energy per unit nitrate than nitrous oxide (Delwiche, 1981).

Denitrification occurs in aerobic bacteria also capable of anaerobic growth in the presence of nitrate and/or nitrite (Payne, 1981). The process can be inhibited by oxygen

(Schuster & Conrad, 1992) and limited by nitrate (Seitzinger, 1994; Weier et al., 1993) and organic matter as an electron donor (Weier et al., 1993). Oxygen is the principal limiting factor in systems exposed to aerobic conditions (Schuster & Conrad, 1992). Nitrate is almost always limiting (< 10 µM) in salt marsh and other marine environments (Slater & Capone, 1989). The sources of $NO_3^-$ include the exogenous sources through groundwater and precipitation and the endogenous source via $NH_4^+$ oxidation.

**Method of Measurement**

Denitrification can be measured using the acetylene inhibition technique (Payne, 1991; Tiedje et al., 1989). Acetylene is used since the structure of acetylene, HC≡CH, is structurally similar to N=N=O. It blocks the reduction of $N_2O$ that accumulates stoichiometrically from $NO_3^-$ or $NO_2^-$ reduction (Ryden & Rolston, 1983). Results have approached the rates measured using very accurate isotope methods when denitrification rates are low (Binnerup et al., 1992). As discussed below, the problems associated with this method include inhibition of other processes in the nitrogen cycle, incomplete diffusion of acetylene into the sample if it is only added to the headspace as is frequently done, contamination of acetylene, and limitation of nitrate in the sample.

Acetylene has been shown to inhibit nitrification by preventing the oxidation of ammonium (Bremner & Blackmer, 1981). If the available nitrate is produced by nitrification, the acetylene inhibition technique can underestimate denitrification (Binnerup et al., 1992). Acetylene also inhibits nitrogen fixation, which would prevent new nitrogen inputs and decrease nitrification rates if the $NH_4^+$ used by nitrifying bacteria is produced by nitrogen fixation.

Another problem is that acetylene must diffuse throughout the sample to inhibit any nitrogen cycle process (Bakar et al., 1994). If complete diffusion does not occur, denitrification rates will be underestimated (Bakar et al., 1994). Even if thorough penetration does occur, bottled acetylene gas routinely contains contaminants, including acetone, that can interfere with denitrification or with the accurate measurement of denitrification rates (Golterman, 1985).

The use of the acetylene block technique has been suggested to require $NO_3^-$ concentrations of approximately 5 to 10 µM to accurately estimate denitrification rates (Ryden & Rolston, 1983; Seitzinger, 1993). Seitzinger (1993) indicates that the acetylene block method may severely underestimate denitrification in $NO_3^-$ poor systems. The method underestimates denitrification rates by not detecting any nitrification-denitrification coupling and by failing to measure all of the denitrification occurring from water column nitrate (Seitzinger, 1993).

Although confronted with many problems, the acetylene inhibition technique can be a reliable and accurate predictor of denitrification rates (Binnerup et al., 1992). Acetylene inhibition is also inexpensive, easy, and sensitive. When no nitrate is added to the sample, this method may reflect in situ rates.

There are various other methods used to measure denitrification rates. Seitzinger (1988) indicates that measuring the decrease in $NO_3^-$ or $NO_2^-$ concentrations in water overlying sediment cores has been used to estimate denitrification rates. Seitzinger's 1988 method can (1) overestimate denitrification by assuming all $NO_3^-$ is denitrified and not reduced to ammonium or (2) underestimate denitrification since the $NO_3^-$ generally used by denitrifiers is obtained from the sediment and not from overlying water (Seitzinger, 1988). Seitzinger (1993) compared methods used to estimate denitrification including a $^{15}N$ isotope tracer method using $^{15}NO_3$ and a method measuring $N_2$ flux. The study found that both methods were accurate, but that the $N_2$ flux method was also able to estimate denitrification arising from nitrification in the overlying water that was underestimated by the $^{15}N$ tracer technique (Seitzinger, 1993). Furthermore, $^{15}NO_3$ pool dilution involves the dilution of $^{15}N_2O$ and may accurately estimate denitrification since other sources of $N_2O$—chemodenitrification, nitrification, and maybe DNRA—produce a small percentage of the $N_2O$ released (Anderson, unpublished data)**,** but the question remains of how well the intracellular pool of $N_2O$ mixes with the added extracellular $^{15}N_2O$**.**

**Dissimilatory Nitrate Reduction to Ammonia (DNRA)**

DNRA can be a quantitatively more important process than denitrification in coastal and estuarine sediments (Anderson, personal communication). The steps in the DNRA pathway are regulated by oxygen and carried out by both obligately anaerobic and facultatively anaerobic bacteria. DNRA is identified by the production of $NH_4^+$ from $NO_3^-$ in excess of the reduced nitrogen needed for growth (Hattori, 1983).

**Mineralization**

Mineralization is the release of organically-bound $NH_4^+$ (Killham, 1994). Ammonification refers to the production of $NH_4^+$ by mineralization and DNRA. Mineralization is affected by soil microorganisms and invertebrates. Animal excretion of simple nitrogenous compounds like uric acids, urea, and ammonia can significantly increase mineralization rates (Rosswall, 1981).

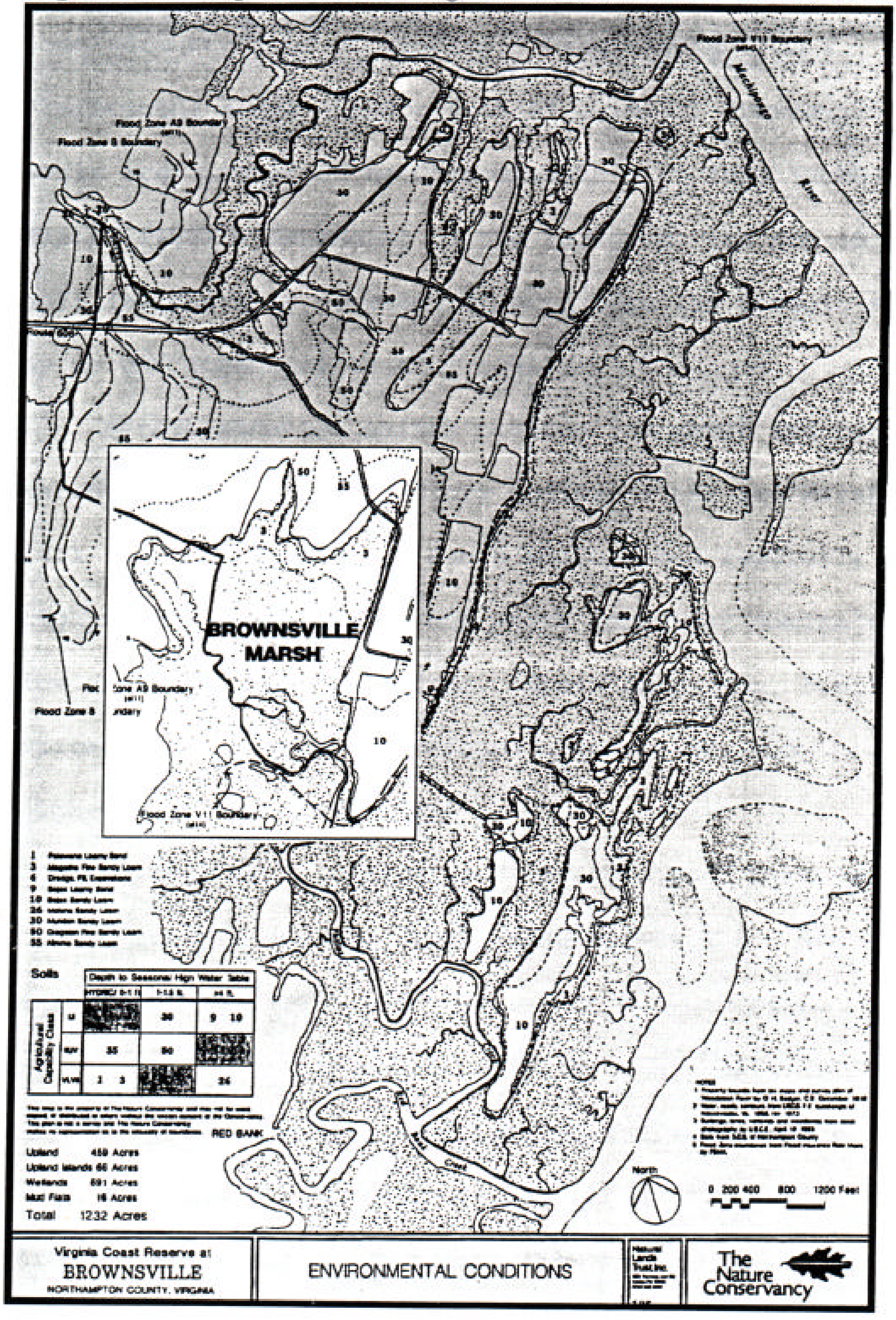
**Assimilation**

Many plants and microorganisms assimilate inorganic nitrogen (Atlas & Bartha, 1993). Nitrogen is assimilated by wetland plants and bacteria as $NH_4^+$-N, $NO_3^-$-N, $NO_2^-$-N, urea-N, and as $N_2O$ (Reddy et al., 1989). Uptake of ammonium is preferred in rooted wetland plant species because $NH_4^+$ dominates the inorganic N pool (Howard-Williams & Downes, 1993).

**Environmental Conditions at Brownsville**

Situated at the Virginia Coastal Reserve (VCR) 3 km east of Nassawadox on the Eastern Shore of Virginia, the Brownsville marsh, illustrated in Figure 2, is owned by The

Figure 2: Map illustrating the Brownsville Marsh site.



Nature Conservancy. Brownsville marsh is part of the Long Term Ecological Research (LTER) program designed for the long-term study of ecosystems. Originating from a Pleistocene ridge (Chambers et al., 1992), Brownsville marsh soils are classified as Chincoteague silt loam (Cobb & Smith, 1989). Depending on the location, the top 15 cm of soil is generally composed of more than 10% organic matter by weight (Chambers et al., 1992).

Strict zonation exists between low marsh and high marsh. *Spartina alterniflora* dominates the low marsh—the tall form near the creek banks which flood regularly during high tide, giving way to the short form that dominates in low areas flooded less often. *Spartina patens, Distichlis spicata*, and *Juncus roemerianus* dominate the mid- to high-marsh (Hmieleski, 1994). Patches of *J. roemerianus* have distinct borders between the *J. roemerianus* and surrounding vegetation. The experiment in this thesis focuses on a patch of *J. roemerianus* located next to Phillips Creek (Figure 3).

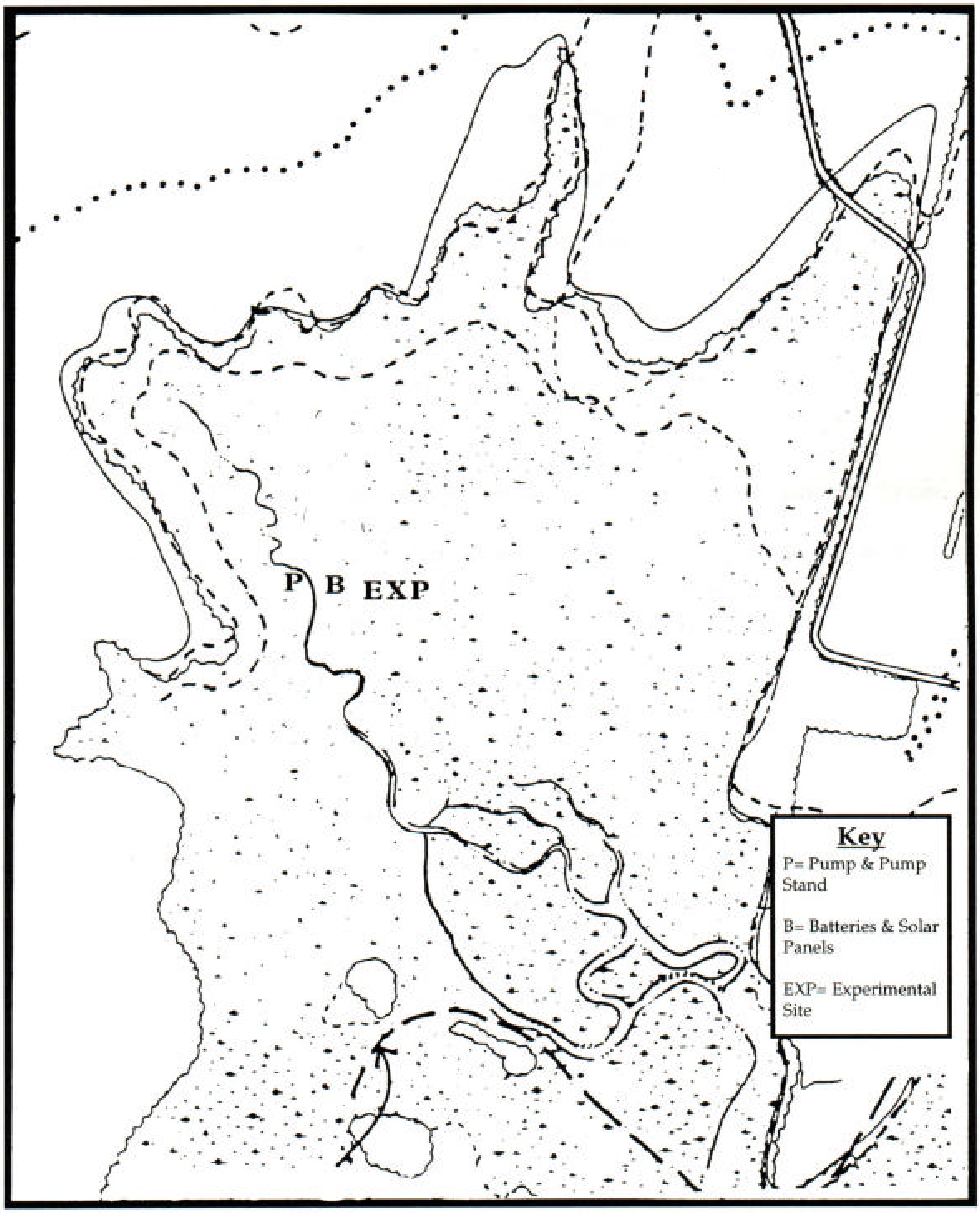
**<u>Factors Affecting Nitrification and Denitrification</u>**

Environmental conditions can influence, inhibit, promote, or limit the processes in the nitrogen cycle. Various physiochemical properties found in salt marshes affect the nitrogen cycle, and when present together, often exert a greater influence on the nitrogen cycle than they can alone (Chalamet, 1985). These properties include: (1) salinity; (2) temperature; (3) soil water content and inundation; (4) Eh; (5) pH; (6) inorganic nitrogen concentrations; (7) vegetation; (8) wrack deposition; and (9) available carbon.

**Salinity**

The salinity at the Brownsville Marsh site ranged from 9 ppt. to 31 ppt. in the high marsh during 1993 (Hmieleski, 1994). The range of values can be affected by tidal inundation, evapotranspiration, rainfall and freshwater runoff from adjacent uplands. Flood events carry salt to the interior of salt marshes, and evapotranspiration of water leaves

Figure 3: Map illustrating the setup of the experimental site.



areas in the marsh interior with increased salinities (Christian et al., 1978). These flood events also remove excess salt build-up when lower salinity water floods the marsh interior diluting the salinity and then exporting the salt when the flood waters drain. Rain events and upland runoff dilute the interior marsh salinities by adding freshwater to the marsh and by exporting salt into tidal creeks. Studies dealing with nitrification fail to mention salinity as a factor affecting the process (Bowden, 1987; Reddy et al., 1989; Kuenen & Robertson, 1994).

Salinity does not seem to affect denitrification rates. Studies reviewing factors that control/affect denitrification rates fail to mention salinity (Knowles, 1982; Seitzinger, 1988; Koch et al., 1992). Denitrifying bacteria live in fresh- and saltwater environments. In fact, denitrification rates have been found to be higher in coastal marine sediments than in freshwater lake or river sediments (Seitzinger, 1988).

**Temperature**

The temperatures at the Brownsville Marsh ranged from $10^{o}$ C to $35.1^{o}$ C during the summer months in 1994 with the monthly average being $23.6^{o}$ C (Porter et al., 1995). The temperatures during October ranged from $2^{o}$ to $16^{o}$ C (Porter et al., 1995). Nitrification and denitrification occur within the range of measured temperatures found at the VCR.

Studies show that production of $NO_3^-$ through nitrification decreases as temperatures fall below $30^{o}$ C, and that nitrification is almost halted at temperatures below $5^{o}$ C (Stevenson, 1986). However, Howard-Williams et al. (1983) found higher nitrification rates at $10^{o}$ C than at $20^{o}$ C when decomposing watercress was added to the soil.

Like nitrification, denitrification occurs readily at temperatures between $10^{o}$ and $45^{o}$ C (Saad & Conrad, 1993). Malhi et al. (1990) concluded “that soil denitrifiers adapted to soil climate.” Kaplan et al (1977) indicated that denitrifying bacteria preferred conditions 5-10$^{o}$ C higher than present in their environment, but further suggested that temperature does not control denitrification rates. Temperature can be important when no other factors are limiting; a condition never true in salt marshes (Anderson, personal communication).

**Soil Water Content, Oxygen Supply, and Inundation**

The supply of oxygen to marsh soils is controlled by the amount of water present, by vegetation capable of oxidizing the rhizosphere, and by bioturbation (macropores). Blum (1993) measured the percent of sediment saturation in creekside and interior marshes at Brownsville. The mean percent saturation (± SD) was 86.9 ± 9.5 percent for the marsh interior and 91.6 ± 6.22 percent for creekside marshes even though the two locations were separated by only 5 m. Soil water content affects the supply of oxygen to the soil which in turn influences both nitrification and denitrification. Increases in oxygen concentrations allow nitrification, but limit or inhibit denitrification. Oxidized rhizospheres in otherwise anaerobic wetland soils or anaerobic microsites in aerobic soils can result in the coupling of nitrification and denitrification (Reddy et al., 1989; Howard-Williams & Downes, 1993).

In their model, Jensen et al. (1994) found little nitrification occurring when oxygen concentrations fell below 10 µM. Nitrification was measured when the oxygen concentrations were above 200 µM indicating the process was limited by oxygen in their model sediment system (Jensen et al., 1994).

Opposite to the effect observed on nitrification, increases in the soil's moisture content tend to increase denitrification rates (Stevenson, 1986). Weier et al. (1993) found that denitrification rates increased as water-filled pore space increased. A biofilm experiment indicated that denitrification was inhibited at oxygen concentrations above 20 µM (Dalsgaard & Revsbech, 1992). However, aerobic denitrification by heterotrophic nitrifiers has been observed (Dalsgaard & Revsbech, 1992).

**Redox Potential**

Eh is used to describe the redox potential and can be used as a crude index of the availability of oxygen in soils (Payne, 1981). Redox potential is the best parameter indicating whether a soil is oxidized or reduced (Patrick & DeLaune, 1977). Blum (1993) measured the Eh of Brownsville marsh and found the values in the top 5 cm ranged from 100 mV to 0 mV and decreased to a low of -100 mV at a depth of 15 cm. Nitrification requires an Eh above 200 mV that generally occurs in the top few millimeters of saturated sediments or in oxidized rhizomes where oxygen is transported to root surfacess (Howard-Williams and Downes, 1993).

Payne (1981) found that denitrification as measured in the field is affected by Eh since nitrate begins to be reduced at an Eh of 200 mV and begins to disappear almost linearly over time to an Eh of -110 mV. Koch et al. (1992) described the theoretical zone of nitrate reduction being below 200 or 250 mV.

**pH**

pH is a measure of the hydrogen ion concentration. The range of pH values at the Phillips Creek Marsh are considered neutral to slightly alkaline and range from 7.5 to 8.5 (Blum, 1993).

Acidic conditions appear to limit nitrification when the pH is 4 or below (Weier & Gilliam, 1986), but heterorophic nitrification takes over at low pH (Anderson, personal communication). The optimal pH range for salt marsh nitrification is between 7 and 9 (Chalk & Smith, 1986). Recently, Killham (1994) indicated that nitrification was not as restricted by pH as had been thought since microbes could be protected by surface attachment, slime production and locations close to mineralization sites.

Denitrification is also affected by pH—occurring slowly in acid soil and faster in slightly alkaline soils (Fillery, 1983). The optimum pH range for denitrification is between 7.0 and 8.0 (Knowles, 1982). Biologically mediated denitrification has been shown to be suppressed in areas where the pH is 3.5 or lower (Sprent, 1987). However, the ratio of $N_2O$ to $N_2$ release increased as pH declines (Knowles, 1982).

**Ammonium and Nitrate Concentrations**

Nitrification and denitrification require substrates, and the availability of $NH_4^+$ and $NO_3^-$ can inhibit, limit, or not affect these processes. Nitrification is generally unaffected by $NO_3^-$ concentrations since $NO_3^-$ concentrations are kept low mainly by anaerobic conditions which restrict nitrification. $NH_4^+$ concentrations up to 200 to 400 µM don't appear to inhibit nitrification rates (Binnerup et al., 1992). Since $NH_4^+$ is the most abundant inorganic nitrogen species in coastal wetlands (Patrick & DeLaune, 1977), nitrification is not likely to be limited by substrate. However, if the $K_m$ value for nitrification is approximately 500µM, $NH_4^+$ in wetlands would be limiting. Similarly, low $NH_4^+$ concentrations limit plant growth (Valiela, 1983) and might therefore also limit the bacterial process of nitrification.

Unlike $NO_3^-$ concentration's lack of effect on nitrification, it is a prerequisite for denitrification (Stevenson, 1986; Seitzinger, 1993; Seitzinger, 1994). The rate of denitrification is found to be almost proportional to the concentration of $NO_3^-$ in overlying water. Denitrification followed first-order kinetics to nitrate when oxidizable substrate was not limiting and $NO_3^-$ concentrations were lower than 645 µM. The process followed zero-order kinetics when carbon containing substrate was limiting or when nitrate was present at concentrations above 645 µM (Fillery, 1983). In another study, $NO_3^-$ concentrations between 20 and 60 µM appeared to be optimal for denitrification (Thomas et al., 1994). High nitrate concentrations altered the products of denitrification effectively decreasing the $N_2/N_2O$ ratio (Weier et al., 1993; Thomas et al., 1994).

The presence of $NH_4^+$ can be an important factor controlling denitrification rates if the $NO_3^-$ used by denitrifying bacteria was derived from nitrification. Seitzinger (1988) indicated that nitrification of $NH_4^+$ in salt marshes and other wetlands was the dominant $NO_3^-$ source used by denitrifying bacteria.

**Vegetation**

Vegetation can affect nitrification and denitrification rates in wetlands through radial oxygen loss (ROL)—the diffusion of oxygen away from roots of wetland vegetation (Reddy et al., 1989). Flooded marsh soils retain aerobic conditions that are created by ROL. Nitrification-denitrification coupling occurs in anaerobic wetland soils where ROL permits the occurrence of nitrification that produces $NO_3^-$ (Reddy et al., 1989; Howard-Williams & Downes, 1993). $NO_3^-$ then diffuses to the adjacent anaerobic areas becoming the substrate for denitrifying bacteria (Howard-Williams & Downes, 1993). Thus, vegetation capable of ROL exerts a positive effect on nitrification and denitrification.

Besides ROL, wetland plants can exude organic matter from their roots which influences denitrification (Reddy et al., 1989). The effect caused by added organic matter is discussed later.

**Wrack Deposition**

Wrack is primarily dead *S. alterniflora* stems which are torn up during winter and early spring storms. They may float on estuarine waters and cover the marsh surface like a large tatami mat. No published paper, to my knowledge, presents experiments dealing with the effect caused by wrack specifically on nitrification or denitrification. During storm events wrack is deposited on the marsh surface killing the underlying vegetation when the wrack layer is thick enough to obscure sunlight and weigh down the underlying vegetation (Knowles, 1989). The soil under the wrack layer retains moisture due to reduced evapotranspiration. The wrack remains until it is either moved by another storm or high tide or until it decomposes. The decomposition of wrack can provide substrates for microorganisms. By reducing the evapotranspiration and by providing an available carbon source, wrack may influence nitrification and denitrification as described in the appropriate sections.

**Organic Matter**

When $NO_3^-$ is not limiting, denitrification is limited by available organic matter from the organic substrate in the sediment. As seen in the previous section, added organic matter provides available carbon that can be used by microorganisms for growth (Nugroho & Kuwatsuka, 1990). Nuhroho and Kuwatsuka (1990) pointed out organic matter affects nitrogen transformations by influencing microbial growth and proliferation.

Electron availability in organic carbon compounds is a controlling factor in heterotrophic activity, and the bulk of denitrifiers are heterotrophs (Knowles, 1982). Denitrification rates increase when organic carbon sources are applied (Nugroho & Kuwatsuka, 1990). In one study the addition of an available carbon source doubled the amount of $NO_3^-$ removed from wastewater (Tam et al., 1992). Similar increases in denitrification rates due to organic carbon additions have been reported by McCarty and Bremner (1992; 1993). However, increases in organic carbon can, in some cases, favor fermentation over denitrification (Anderson, personal communnication).

**Study Objective**

The experiment described here attempts to answer how nitrification and denitrification are affected by: (1) increased inundation; and (2) presence or absence of wrack. Other environmental conditions were measured to provide an indication of how increased inundation, and the presence or absence of wrack affect the processes of nitrification and denitrification. Specifically, redox potentials, bulk densities, percent moistures, nutrient concentrations, nitrification rates, and denitrification rates were measured and tested for the influence by the different treatments.

Figures 4A and 4B illustrate the postulated effects of various environmental properties on nitrification and denitrification. The analyses shown in figures 4A and 4B demonstrate interactions between oxygen and organic matter and the processes affected by these variables. For instance, wrack exerts a positive effect on soil water content by reducing evapotranspiration (Figure 4A). Soil water content exerts a negative effect on oxygen concentrations by reducing diffusion. Oxygen exerts a positive effect on the oxidation processes (steps 1 and 2), but a negative effect on the process of reduction (steps 3, 4, and 5). Therefore, the effects of each step are combined to arrive at how wrack influences the oxidation and reduction of the N-containing compounds. In this case, wrack is hypothesized to exert a negative effect on the oxidation process since it decreases oxygen concentrations which in turn reduces the redox potential. Likewise, wrack is hypothesized to exert a positive effect on the reduction of the nitrogenous compounds by excluding oxygen from the soil (Figure 4A) or by providing organic carbon required for denitrification (Figure 4B).

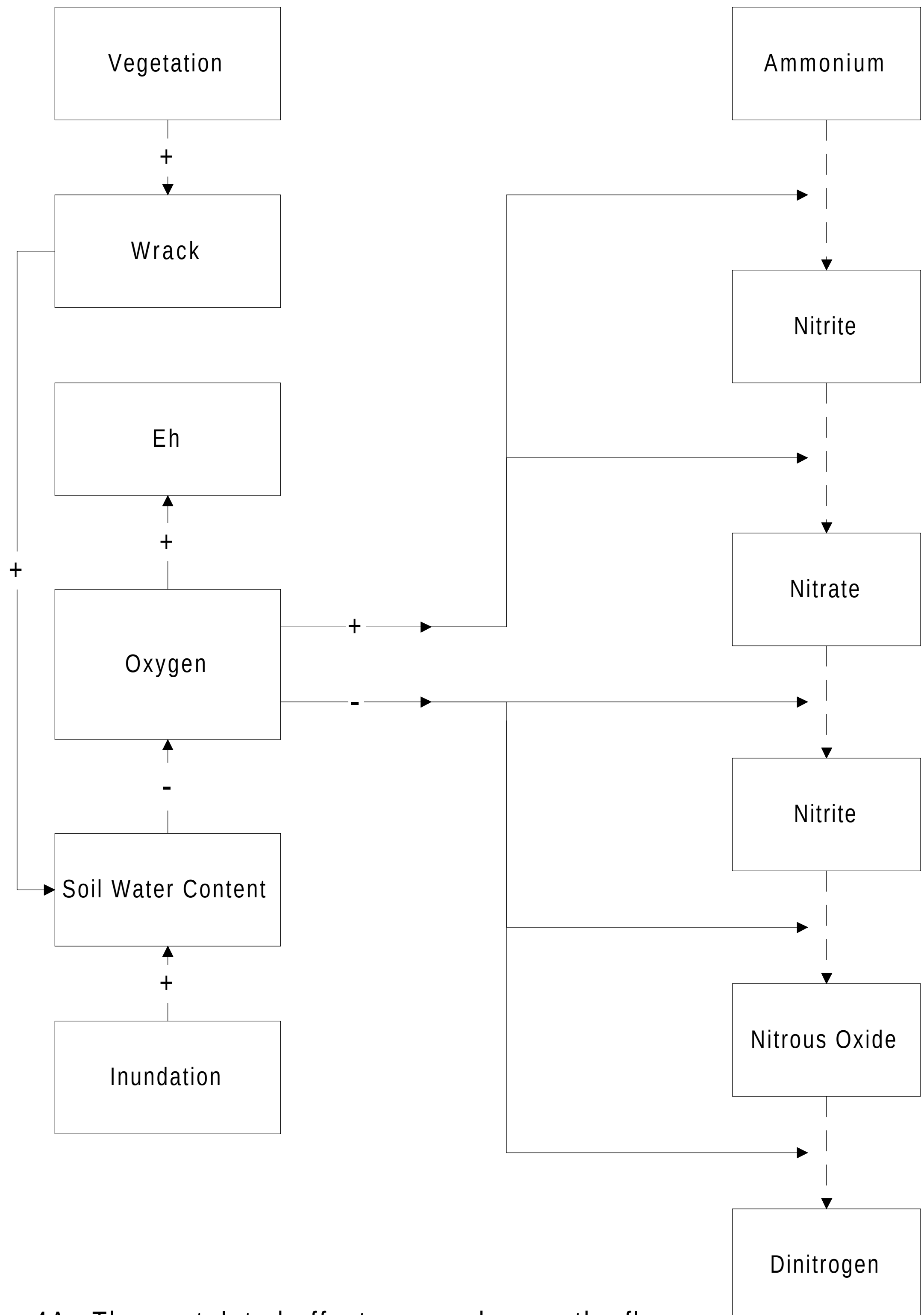



Figure 4A: The postulated effect oxygen has on the flows of nitrogen in nitrification and denitrification.

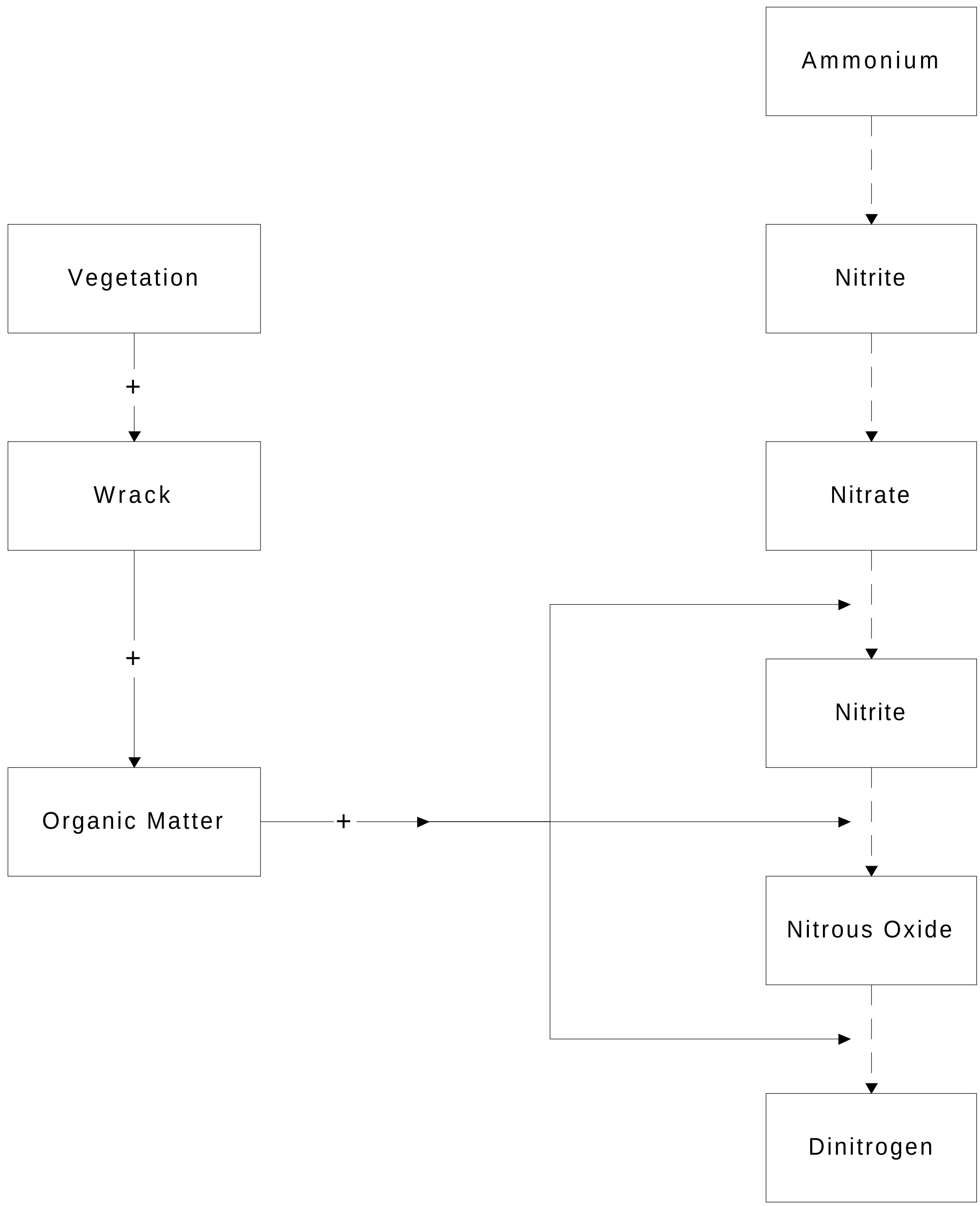



Figure 4B: The postulated effect available carbon has on the flows of nitrogen in nitrification and denitrification.

# Hypotheses

A. Flooding:

FH1: Increased flooding will decrease the available $O_2$ and thereby lower the Eh.

FH2: Pumping tidal creek water onto the flooded plots will increase concentrations of $NO_3^-$.

FH3: If FH1, the flooding will decrease nitrification rates.

FH4:
- a. If $NO_3^-$ from tidal water limits denitrification and FH2 occurs, the first two hypotheses will lead to increases in denitrification rates.
- b. If $NO_3^-$ from nitrification limits denitrification and FH3 occurs, flooding will decrease the rate of denitrification.
- c. If $NO_3^-$ does not limit the rate of denitrification, flooding and nitrification will not affect denitrification rates.

B. Wrack:

WH1: Wrack will lower the Eh of marsh soil.

WH2: Wrack will increase the percent moisture in the soil.

WH3: Vegetated areas will have higher nitrification rates than wrack-covered areas if wrack lowers the $O_2$ in the soil.

WH4: The presence of wrack will increase denitrification rates because of WH1.

C. Interaction:

IH1: Flooded wrack-covered sections will have higher denitrification rates than sections just flooded or wrack-covered.

## Methods ands Materials

**Study Site**

The experimental site is located at 37$^{o}$ 27' 38.5" N, 75$^{O}$ 50' 4.96 W and is surrounded on 3 sides by uplands consisting of either farmlands or pine forests (Hmieleski, 1994) (Figure 2). Figure 3 illustrates the position of the experimental site in relation to Brownsville Marsh and Phillips Creek. The arrangement of the various treatments is illustrated in Figure 5.

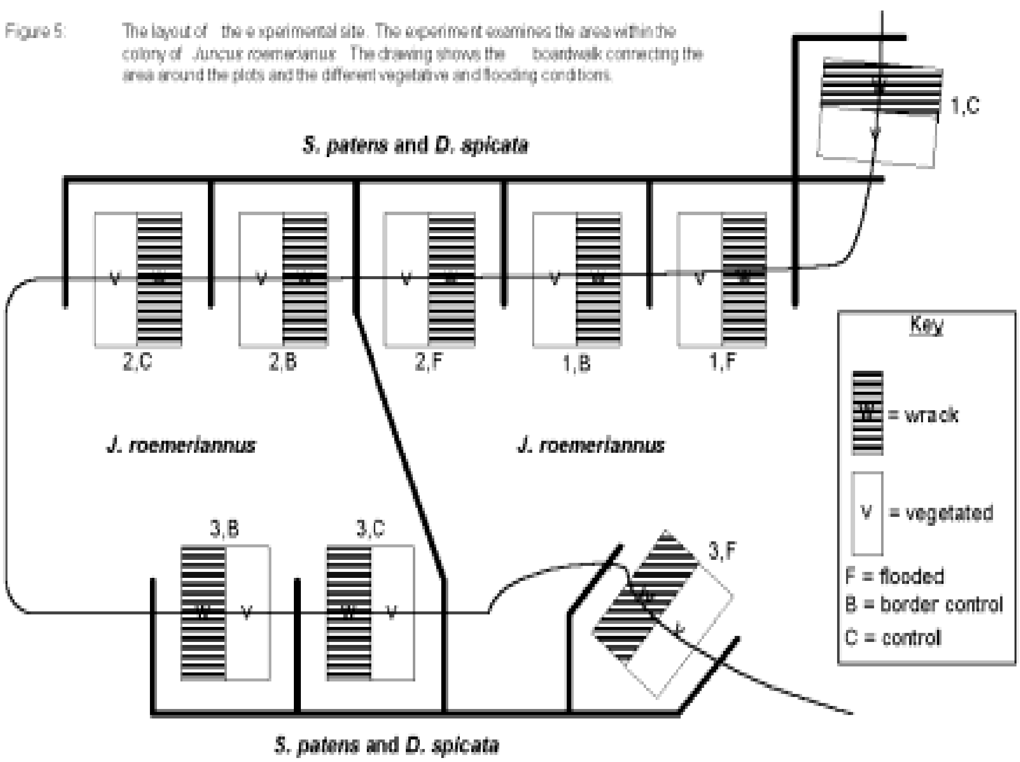



Figure 5: The layout of the experimental site. The experiment examines the area within the colony of *Juncus roemerianus*. The drawing shows the boardwalk connecting the area around the plots and the different vegetative and flooding conditions.

**Experimental Design**

**Blocks and Plots**:

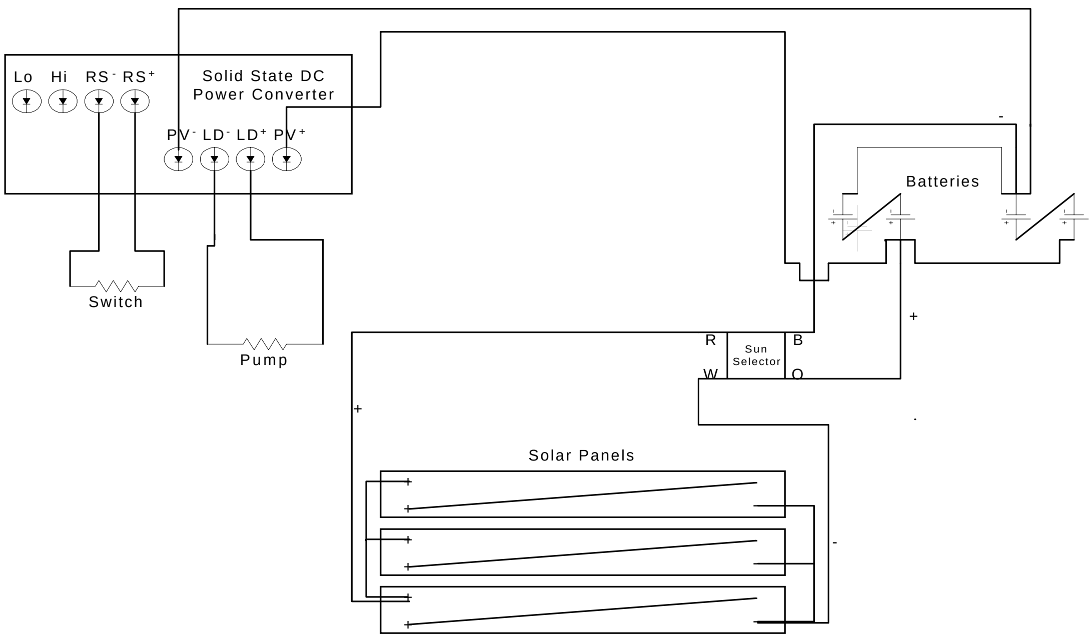
Each of three blocks contained three 3-m by 4-m plots (Figure 5). 'Right' and 'Left' indicate the sides of the plots as viewed from the boardwalk neighboring the plots. The plots were chosen so that *S. patens* and *D. spicata* dominated the front half, while *J.*

*roemerianus* dominated the back half. The right back half of each plot, designated as **J,** supported unaltered vegetation. Six weeks before the first measurements were to be taken, a layer of wrack was placed over the vegetation on the left side of each plot, designated as **W.** I compared the **J** quarter with that portion of the **W** side that had *J. roemerianus*. The wrack in the **W** sections remained held down by 3/4-inch mesh (1.905-cm) bird netting. Four 2-ft (60.96-cm) sections of wire were folded in half to hold the bird-netting in place. The three plots in each block were designated as Flooded, **F,** Border Control, **BC,** or Control, **C**. The only difference between the **F** and **BC** plots was the flooding received by the F plots. A border, composed of a vertically placed 3/8-inch (0.95-cm) thick plywood 20 cm wide, slowed water flow out of the **F** plots. The border was coated with three coats of Thompson's Water Seal to prevent decomposition. After drying, the border was inserted 10 cm into the marsh soil. Gaps were left between the pieces of plywood comprising the border to allow water to flow out of the plots. The **BC** plots were controls used to detect the effects the border and the 1/2-inch (1.27-cm) PVC pipes had on the measured results. The **C** plots had no border, received no flooding, and were delineated by 1/2-inch (1.27-cm) PVC pipes in each corner.

**Electrical system**

The electrical system used in the experiment is illustrated in Figure 6. A float switch (Thomas Products LTD. Model 4200 P/N 24251) activated the pump by closing the switch's circuit when the water level rose 0.5084 m above mean sea-level. Two submersible pumps were used during the experiment to flood the F plots with water from Phillips Creek. The pump was supported by a stand that extended out into Phillips Creek (Figure 3). A Cimaron 4-in (10.16-cm) SolarSub pumped 7.57 L/min from April 7 to the first week in July when it failed. The Cimaron SolarSub was replaced by a SolarJack (4-in SDS series) that pumped up to 9.5 L/min from July 23 until September 25 when the system was disconnected. A solid state relay (Crydom relay), replaced by a solid state DC power converter (SolarJack PC10-28H) when the new pump was installed, connected the float switch and the pump to the 14 gauge wire leading to the batteries.

Figure 6: A schematic of the electrical system. Included are the four batteries, solar panels, DC power converter, pump, float switch, and a charge controller (Sun Selector).




The pump was powered by four 12 V DC batteries (Reliant GPR-1285, Concorde Battery Corporation) that were divided into 2 sets. Each set contained 2 batteries connected in series. The 2 sets were then arranged in parallel to promote even electrical delivery and long battery life. The location of the battery stand is illustrated in Figure 3. Four solar panels (Siemens M55 Solar Electric Module) were supported on a 2.44-m galvanized pipe 10.16 cm in diameter that was located half-way between Phillips Creek and the Blocks 1 and 2 (Figure 3). The panels were arranged into 2 sets, and the panels in each set were connected in series. The 2 sets were arranged in parallel. Each set of panels supplied 24 V DC to recharge the batteries in sunlight. A charge controller (Sun

Selector M-8), connected between the batteries and the panels, controlled the charging of the batteries.

**Water Delivery System**

The **F** plots were designed to be inundated during each high tide for approximately 3 h. The flow rate to each of the three **F** plots was initially as high as 2.5 L/m, but was increased to as much as 3.14 L/m when the new pump was installed. Water left the pump and traveled through a 3/4-in hose and into a 3/4-in (1.9-cm) PVC pipe system that ran approximately 30 m connecting to two valved Y joints that split the flow of water into 3 equal flows. Each of the new flows was measured over 5 min intervals to assure equal flow rates. PVC pipes, 1.9 cm in diameter, delivered the water to the F plots. The PVC pipe running to each plot was connected to a "T" joint, splitting the flow and diverting it around both sides of the plot. Upon reaching the middle of either side of the plot, the water flowed through another "T" joint with a vertical pipe open to the atmosphere to balance the water flow on both sides of the plot. Another "T" joint diverted the flow into a rectangle, connecting the flows from both sides. These last two pieces of PVC had ten holes drilled into the top and bottom of the tube to allow the pressurized water to flow out of the water delivery system and into the **F** plots.

**Sample Collection**

**Core Samples**:

Measurements of nitrification and standing stocks of $NH_4^+$, $NO_3^-$, and $NO_2^-$ were taken during June, August, September, and October. Denitrification estimates were limited to August, September, and October during 1994. The data collected for June, August and September were obtained following the same methods. The data from October were taken outside the experimental area to determine how denitrification, nitrification, and the standing stocks of $NH_4^+$, $NO_3^-$, and $NO_2^-$ were affected by drying over a period of hours.

During June, August, and September, samples were taken over a 3 day period each month: 1) June 3-5; 2) August 26-28; and 3) September 23-25. One block was sampled each day during the sampling trip—Block 1 on the first day, Block 2 on the second day, and Block 3 on the last day. In October, 40 cores were taken and analyzed in one day.

Acrylic core tubes (Cadillac Plastics) were 15.24-cm long, and had an inside diameter of 3.81 cm and an outer diameter of 4.45 cm. Eight holes 5/64 in (0.2 cm) in diameter were cut into the core tube at the location where the 3-cm soil core would rest after being sealed in the tube. Figure 7 illustrates the core tube as filled with a soil sample.

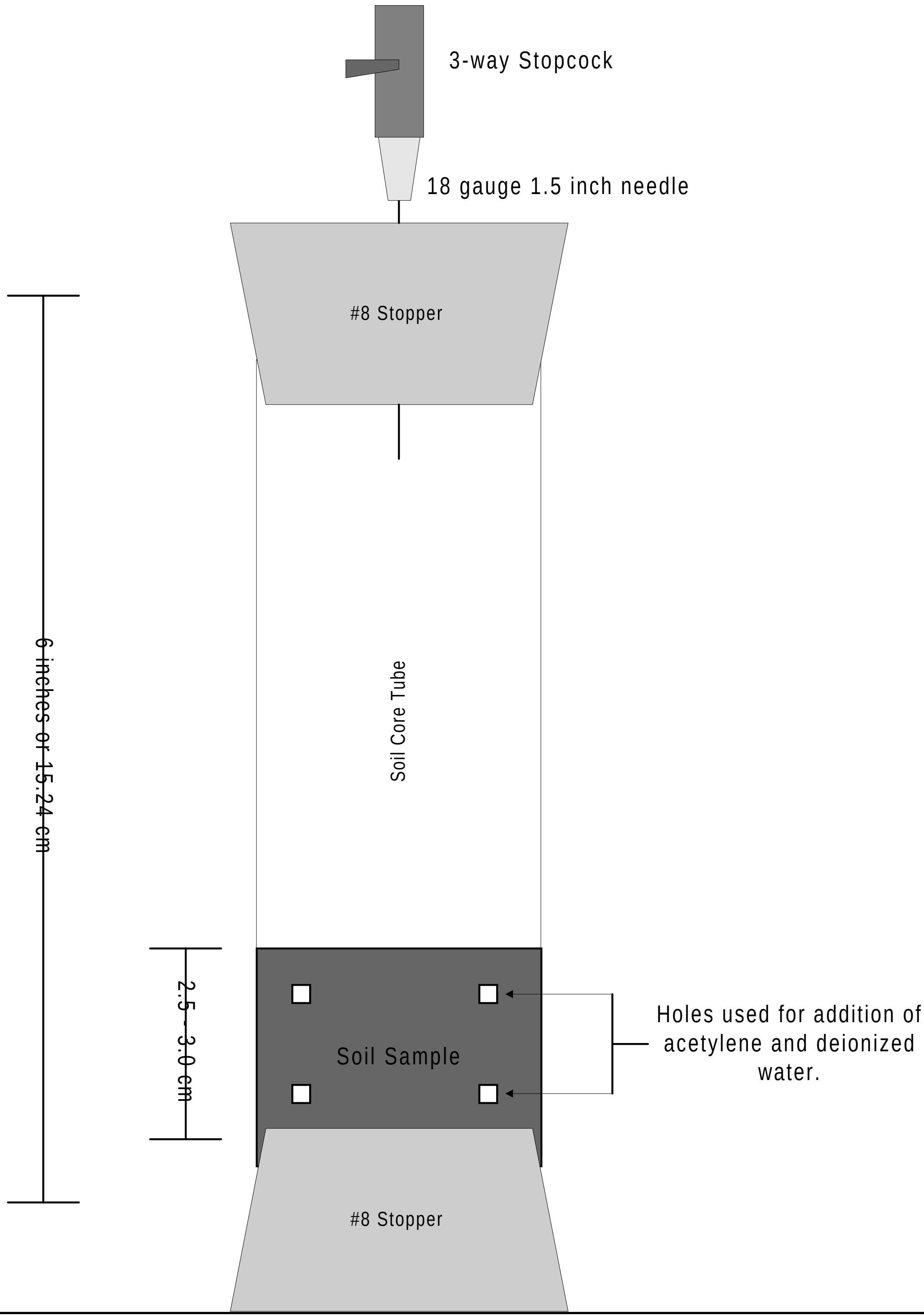
Core samples were obtained by pressing the core tube down into the soil and removing the top 3 cm of marsh soil. A total of 270 cores was taken during each three-day sampling trip in June, August, and September. Ninety cores were taken from each block—thirty cores per plot. After obtaining the soil core, a #8 stopper (Fisher) was used to seal the bottom of the core tube.

The 15 cores from each section—**J** and **W—**were divided into five incubation periods with three cores per period: (1) 0 h with acetylene, labeled as '0A'; (2) 1 h cores injected with acetylene, labeled as '1A'; (3) 1 h cores with deionized water added, labeled as '1'; (4) 6 h cores with added acetylene, labeled as '6A'; and (5) 6 h cores injected with deionized water, labeled as '6'.

Three more cores were taken from each side—**J** and **W—**of each plot—**C**, **BC**, and **F**—for a total of 54 cores. These cores were taken to determine the percent moisture, bulk density, and volume of water in each core.

In October, 48 cores were taken from within the *J. roemerianus* patch. Twenty four cores were labeled as "wet," and the remaining cores were labeled as "dry." Twenty cores in each treatment were divided into five incubation times: (1) 0 h with acetylene,

Figure 7: The core tube assembly including a soil sample, the needle, 3-way stopcock, and the stoppers. The stoppers are sealed with electrical tape to prevent moisture or gas loss from occurring.



labeled as ‘0A’; (2) 1 h cores injected with acetylene, labeled as ‘1A’; (3) 1 h cores with deionized water added, labeled as ‘1’ (4) 6 h cores with added acetylene, labeled as ‘6A’’; and (5) 6 h cores injected with deionized water, labeled as ‘6’. Each incubation time had four replicates. The remaining four cores in each treatment were analyzed to determine the percent moisture, bulk density, and volume of water in each core.

**June, August, and September**

Back in the laboratory of the VCR/LTER in Oyster, VA, marsh soil was removed from the exterior of the cores, and measurements were taken to determine the volume of soil and standing water, if any, in each core tube. The bottom stopper was then pushed firmly in place and sealed to the core with black vinyl electrical tape. Another #8 stopper, with a 18 gauge needle running through it, was placed in the top of the core tube. A three-way stopcock (Baxter K169RA) was connected to the top of the needle. The stopper on top of the core tube was pushed firmly in place and sealed with colored vinyl electrical tape depending on the incubation period to which it belonged.

Two ml of acetylene saturated deionized water were added to the acetylene treatment through the holes drilled in the sides of each core tube (designated as “A”). After the injection, the cores were incubated at field temperatures. The cores that did not receive acetylene were injected with 2 ml of deionized water at the same time the acetylene saturated water was added.

At the end of the incubation period, 29 ml of 2 N KCl were added to each core through the stopcock and needle. The 2 N KCl slows the transformation of the nitrogen in the core. Immediately after adding the 2 N KCl, the cores were shaken for one minute to break up the core and assure complete distribution of KCl throughout the core.

**October**

The October “wet” cores were sealed using the same method used during June, August, and September. The "wet" cores remained sealed to prevent moisture loss, while the "dry" cores were left open and air dried under a fan overnight (approximately 12 hours). After the drying period, the "dry" cores were sealed as with the "wet" cores. The cores were treated and incubated as described above.

**Sample Processing**

Two samples were taken from each core after the addition of the 2 N KCl and shaking took place: (1) a gas sample was analyzed for $N_2O$; and (2) a liquid sample was analyzed for $NH_4^+$, $NO_3^-$, and $NO_2^-$. Nitrification rates were determined from the $NH_4^+$, $NO_3^-$, and $NO_2^-$ concentrations.

The gas sample was drawn into a 20-ml plastic syringe (BD) that was sealed by removing the three-way stopcock—that had previously sealed the coretube—and leaving it connected to the syringe. After taking the gas sample, each water sample was centrifuged in a 50-ml polypropylene centrifuge tube (Corning Brand) for 4 min to remove floating sediment from the water samples (International Clinical Centrifuge Model # 4171D, International Equipment Corporation). The supernatant was transferred to another 50-ml centrifuge tube and kept on ice until arrival at the lab.

Once at East Carolina University, the samples were filtered through 1.5-µm filters (Gelman 934-AH glass microfibre filters) that had been ashed for four hours to remove any traces of nitrogen. The samples were then placed in the cold room at 4.5$^{o}$ C until analyzed.

**<u>Laboratory Analyses</u>**

**$N_2O$ and Denitrification Analyses**

The gas samples were analyzed against $N_2O$ standards using a gas chromatograph (Shimadzu GC8A) equipped with an electron capture detector and an integrator (Shimadzu CR 601) that printed the area under the $N_2O$ curve. The area under the curve from samples of known $N_2O$ concentrations was used in a regression to provide an equation to calculate concentrations of $N_2O$ from the areas obtained from the core samples (See Appendix A).

Using the $N_2O$ concentrations corrected for that in the dissolved phase (See Appendix A), a denitrification rate ($N_2$OT01A), in nmol $m^{-2}$ $h^{-1}$, was calculated from the data by subtracting the concentration of $N_2O$ in the 0A ($N_2$OT0A) cores from the concentration of $N_2O$ in the 1A ($N_2$OT1) cores and dividing the difference by the incubation time in hours:

$$N_2OT01A = (N_2OT1A - N_2OT0A)/1 \quad [1]$$

**$NH_4^+$ Analysis**

A modified form of the Solorzano Method (Solorzano, 1969) was used to analyze the KCl extracts for the concentration of ammonium.  The modification was a scaling down of the analysis due to very high $NH_4^+$ concentrations.  Five ml of sample were combined with 5 ml of deionized $H_2O$ to give 10 ml of sample that would be analyzed. The spectrophotometer reading was then doubled to account for the dilution.

After mixing, the samples were allowed to develop overnight—approximately 15 hours.  The long development time was necessary to allow full development of the color due to the high levels of ammonium in the samples.  The developed samples were then analyzed on a spectrophotometer (Milton Ray Spectronic 1201) at 640 nm.

Along with the water from the core samples, $NH_4^+$ standards were analyzed in a similar fashion.  Eleven standard concentrations were analyzed:  0 (Blanks), 5, 10, 20, 40, 60, 80, 100, 120, 240, and 480 µM.  A regression was run on the standards and their absorbances.

**$NO_3^-$ Analysis**

Nitrate analysis was conducted following the procedure designed by Jones (1984).

The technique was modified to use only 5 ml of sample with 5 ml of deionized water instead of the 10 ml of sample used by Jones.

The KCl extracts from the cores were removed from the cold room and allowed to warm to room temperature. After warming, 5 ml of sample and 5 ml of deionized water were added to a 50-ml centrifuge tube. Two ml of ammonium chloride solution and 0.5 g of wet spongy cadmium were added to the water sample. The centrifuge tube was then capped and allowed to shake in an automatic shaker (Eberback Corporation) for 90 minutes. Shaking with cadmium reduces the $NO_3^-$ to $NO_2^-$. The last month's $NO_3^-$ analysis shook for only 60 min. Experiments showed that shaking for 90 min and 60 min resulted in similar measurements due to the scaling down of the Jones method.

After shaking, 10 ml of the liquid was transferred into a 25-ml Erlenmeyer flask followed by the addition of 0.4 ml of color reagent. The flask was swirled to assure good mixing and the color was allowed to develop for 15 minutes in dim light.

Standards of $NO_3^-$ were made in the following concentrations: 0 (blank), 0.5, 1, 1.5, 2, 3, 4, 5, and 10 µM. A liquid sample from the core samples and standards were read in a spectrophotometer (Milton Ray Spectronic 1201) at 540 nm. A regression was run on the $NO_3^-$ standards and their absorbances.

**$NO_2^-$ Analysis**

The $NO_2^-$ analysis used the color reagent from the $NO_3^-$ analysis. Five ml of KCl extract were placed into a 15-ml Erlenmeyer flask to which 0.2 ml of color reagent was added. The sample was swirled to allow complete mixing. The samples were analyzed on the spectrophotometer at 540 nm after the color developed for 15 minutes.

Standards were mixed containing $NO_2^-$ concentrations of 0 (Blank), 0.5, 1, 1.5, 2, 3, 4, and 5 µM. A sample from the cores and standards was read in a spectrophotometer set at 540 nm. A regression was run on the $NO_2^-$ standards and their absorbances.

**Nitrification Analysis**

Nitrification rates in μmol $m^{-2}$ $h^{-1}$ were determined using the data obtained from the analysis of $NH_4^+$, $NO_3^-$, and $NO_2^-$. Formulas 2, 3, and 4 show how nitrification rates were calculated. The rates, on the left, represent the change in chemical species between the samples treated with acetylene and those treated with deionized water.

$$NH_4^+T6A6 = (NH_4^+T6A - NH_4^+T6)/6 \quad [2]$$

$$NO_3^-T66A = (NO_3^-T6 - NO_3^-T6A)/6, \text{ and} \quad [3]$$

$$NO_2^-T66A = (NO_2^-T6 - NO_2^-T6A)/6 \quad [4]$$

where $NH_4^+$, $NO_3^-$, and $NO_2^-$ represent the concentration of chemical species, T6 indicates a deionized treated sample incubated for 6 h, T6A indicates an acetylene treated sample incubated for 6 h.

**Redox Potential**

During each sampling period, the redox potential was measured 3 times in each of the 2 areas sampled in each plot. The redox potentials were measured using an Orion analyzer (Ionalyzer Model 407A) sampled using a platinum tipped electrode coupled to a standard pH reference electrode. The pH reference electrode accounts for the $H^+$ concentrations, and no correction for $H^+$ concentration needed to be made. To assure accurate measurements, the method was tested on Zo Bell's solution. Inserted into the top cm of the soil, the electrode was left in place for 2 min to allow the reading to stabilize.

**Bulk Density and Percent Moisture**

Three soil cores were taken from each half plot during August and September to obtain measurements of bulk density and percent moisture. Bulk density measurements were obtained using the method outlined by Blake and Harlge (Blake and Harlge, 1986).

The percent moisture was determined following Gardner's method (Gardners, 1986). The soil core's dry mass was subtracted from the wet soil core's mass to obtain the mass of the water in the core. The water's mass was divided by the wet soil core's mass, and the resulting number is multiplied by 100 to obtain the soil's percent moisture.

**Elevation Data**

The pump, the creekside water-level recorder, and each plot were surveyed to the Brownsville high definition benchmark which was located 5 m from the plots using a TOPCON Autolevel (AT-F2).

**Statistical Analysis**

The SAS statistical software analyzed the data with a general linear model (GLM) procedure. This analysis provides a means of discovering how the main effects of Block, Flood, and Vegetation affected the measured parameters. The interactions between the main effects are noted and described. Tukey's multiple comparison method was used at the 0.05 level to detect significant differences between the treatments.

Only a few of the measured variables fit the assumption of normality. However, the normality of the data was not of great concern since a few extreme outliers were responsible for the data not fitting the assumption (Holbert, personal communication). Negative rates were left negative and not adjusted to zero to indicate the total movement of inorganic nitrogen. A negative nitrification rate, for example, indicates that the concentration of $NO_3^-$ or $NO_2^-$ measured with acetylene were higher than those measured without added acetylene.

## Results

The following two sections present the data from the experiment. The first section, long-term experiments, shows how the main effects of Block, Flood, and Vegetation (Veg) and their interactions affected the measured data. In the next section I present data from October that illustrates how the variables were affected by a short-term drying period. The variables—redox potential, bulk density, percent moisture, nitrification estimated using $NO_3^-$ and $NO_2^-$, and denitrification—are described as to how they were affected by the different treatments.

### Long-Term Experiments

The means, standard deviations, and Tukey groupings at the 0.05 level of the measured data as affected by the main effects are presented in Table 2 for June, Table 6 for August, and Table 10 for September. Tables 3, 7, and 11 illustrate the means and standard deviations of the measured data related to the Block*Flood interaction in June, August, and September, respectively. The means and standard deviations related to the Block*Veg interaction are displayed in Tables 4, 8, and 12. Lastly, Tables 5, 9, and 13 illustrate the means of the measured data related to the Flood*Veg interaction.

#### June

##### $NO_3^-$ and $NO_2^-$ Concentrations

The means of the $NO_3^-$ and $NO_2^-$ concentrations from individual cores are shown in Tables 2 - 5. The $NO_3^-$ concentrations ranged from 0.12 to 15.22 µM, and the $NO_2^-$ concentrations ranged from undetectable to 2.73 µM. The main effects of Veg ($p = 0.0338$) and Flood ($p = 0.0210$) were significant for $NO_3^-$ concentrations (Table 2). For $NO_2^-$ concentrations, only the interaction effects of Block*Flood ($p = 0.0001$) and Block*Veg ($p = 0.0205$) were significant (Tables 3 & 4).

The Veg effect resulted from the wrack-covered areas having statistically higher (p

$< 0.05$) $NO_3^-$ concentrations than the vegetated sections (Table 2).

The Flood effect is a consequence of the **C** plots having significantly higher ($p < 0.05$) $NO_3^-$ concentrations than the **F** plots (Table 2). The $NO_3^-$ concentrations in the **BC** were statistically similar to the concentrations found in the **C** and **F** plots.

The Block*Flood interaction on $NO_2^-$ concentrations is a consequence of several factors (Table 3). First, the **C** plot in Blocks 1 and 2 had the highest $NO_2^-$ concentrations, while it had the lowest $NO_2^-$ concentrations in Block 3. Furthermore, the **BC** plots in Blocks 2 and 3 had $NO_2^-$ concentrations between that of the **C** and **F** plots, whereas it had the lowest $NO_2^-$ concentrations in Block 1. Third, the **F** plots had highest $NO_2^-$ concentrations in Block 3, the lowest in Block 2 and the middle in Block 1 (Table 3). Lastly, the magnitude of the difference in $NO_3^-$ concentrations between the flooding treatments varied greatly between the blocks.

The Block*Veg interaction results from the wrack-covered sections having higher $NO_2^-$ concentrations than the vegetated areas in Blocks 1 and 3, while the vegetated sections had higher $NO_2^-$ concentrations than the wrack-covered areas in Block 2 (Table 4). Another cause of the interaction is that the magnitude of the difference in $NO_2^-$ concentrations between vegetated and wrack-covered sections varied greatly between blocks.

**Nitrification**

Only nitrification was estimated in June. Table 2 reviews the means of the data reflecting the main effects. Using $NO_3^-$, nitrification rates ranged from -60.80 to 18.44 μmol $NO_3^-$ $m^{-2}$ $h^{-1}$. The extremes were located in Block 2. The lowest rate was measured in a control wrack-covered area, and the highest rate was measured in a flooded vegetated area. Only the main effect of Veg was significant ($p = 0.0186$). Vegetated areas had significantly higher ($p < 0.05$) rates than wrack-covered sections (Table 2).

Using $NO_2^-$, nitrification rates ranged from -16.59 to 9.32 µmol $NO_2^-$ $m^{-2}$ $h^{-1}$. Both the lowest and highest rates were measured in the wrack-covered area of the **F** plot in Block 3. None of the main effects nor interaction effects were significant (Table 2 - 5).

Table 2: The means, standard deviations, and Tukey groupings for June's data.

| | | Block | | | Flood | | | Vegetation | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Measure of: | 1 | 2 | 3 | Border | Control | Flood | Juncus | Wrack |
| Nitrate - T0 | Mean | 1.56 | 2.21 | 1.47 | 1.36 | 2.82 | 1.12 | 1.21 | 2.34 |
| ( µM) | Std. Dev. | 1.05 | 3.56 | 0.53 | 1.11 | 3.41 | 0.69 | 0.88 | 2.93 |
| | Tukey Grouping | A | A | A | D/E | D | E | G | H |
| Nitrite - T0 | Mean | 1.11 | 0.97 | 1.03 | 0.92 | 1.02 | 1.16 | 1.06 | 1.01 |
| ( µM) | Std. Dev. | 0.48 | 0.36 | 0.64 | 0.37 | 0.54 | 0.57 | 0.45 | 0.55 |
| | | A | A | A | D | D | D | G | G |
| Nitrification - Nitrate | Mean | -3.17 | -6.75 | 1.99 | -0.66 | -8.30 | -1.01 | 1.94 | -7.21 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 6.37 | 20.13 | 8.57 | 9.99 | 17.23 | 13.70 | 8.76 | 15.87 |
| | Tukey Grouping | A | A | A | D | D | D | G | H |
| Nitrification - Nitrite | Mean | -0.52 | -0.97 | -1.97 | -0.32 | -2.42 | -0.64 | -1.23 | -0.93 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 4.20 | 2.59 | 5.77 | 2.26 | 3.44 | 5.97 | 3.62 | 4.60 |
| | Tukey Grouping | A | A | A | D | D | D | G | G |

Note: Tukey goupings are labelled by Treatment. Block uses 'A', 'B', and 'C. Flood uses 'D', 'E', and 'F'. Vegetation uses 'G' and 'H'. Measurements with differing groupings indicate a significant difference ($p < 0.05$) between the means.

Table 3: The means and standard deviations for the B*F interaction for June's data.

| | | | Block 1 | | | Block 2 | | | Block 3 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Measure of: | Border | Control | Flood | Border | Control | Flood | Border | Control | Flood |
| Nitrate - T0 | Mean | 1.47 | 2.44 | 0.90 | 1.29 | 4.58 | 0.77 | 1.34 | 1.39 | 1.68 |
| (µM) | Std. Dev. | 0.82 | 1.13 | 0.67 | 1.80 | 5.43 | 0.43 | 0.35 | 0.57 | 0.65 |
| Nitrite - T0 | Mean | 0.90 | 1.59 | 0.91 | 0.92 | 1.09 | 0.89 | 0.94 | 0.49 | 1.68 |
| (µM) | Std. Dev. | 0.37 | 0.38 | 0.40 | 0.53 | 0.29 | 0.21 | 0.23 | 0.21 | 0.65 |
| Nitrification - Nitrate | Mean | -3.68 | -2.38 | -3.35 | -3.53 | -21.23 | 2.10 | 6.42 | 0.45 | -3.34 |
| (µmole m^-2 h^-1) | Std. Dev. | 5.75 | 1.89 | 10.30 | 13.08 | 24.85 | 17.75 | 7.47 | 4.31 | 12.96 |
| Nitrification - Nitrite | Mean | 1.50 | -4.01 | 0.38 | -1.00 | -1.72 | -0.31 | -1.70 | -1.30 | -3.34 |
| (µmole m^-2 h^-1) | Std. Dev. | 1.63 | 4.25 | 4.62 | 2.06 | 3.68 | 2.32 | 1.94 | 1.60 | 12.96 |

Table 4: The means and standard deviations for the B*V interaction for June's data.

| Variable | Measure of: | Juncus Block 1 | Juncus Block 2 | Juncus Block 3 | Wrack Block 1 | Wrack Block 2 | Wrack Block 3 |
|---|---|---|---|---|---|---|---|
| Nitrate - T0 | Mean | 1.48 | 0.80 | 1.36 | 1.65 | 3.63 | 1.58 |
| ( µM) | Std. Dev. | 1.24 | 0.61 | 0.53 | 0.83 | 4.70 | 0.53 |
| Nitrite - T0 | Mean | 1.02 | 1.19 | 0.98 | 1.21 | 0.75 | 1.09 |
| ( µM) | Std. Dev. | 0.50 | 0.37 | 0.51 | 0.48 | 0.17 | 0.78 |
| Nitrification - Nitrate | Mean | -3.75 | 4.31 | 8.56 | -2.59 | -16.58 | -1.30 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 4.50 | 9.90 | 7.08 | 8.12 | 22.21 | 7.54 |
| Nitrification - Nitrite | Mean | -0.37 | -1.89 | -1.83 | -0.68 | -0.15 | -2.05 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 4.75 | 2.87 | 2.08 | 3.81 | 2.15 | 7.11 |

Table 5: The means and standard deviations for June's data for the F*V interaction.

| Variable | Measure of: | Juncus Border | Juncus Control | Juncus Flood | Wrack Border | Wrack Control | Wrack Flood |
|---|---|---|---|---|---|---|---|
| Nitrate - T0 | Mean | 1.09 | 1.68 | 0.88 | 1.67 | 4.12 | 1.36 |
| ( µM) | Std. Dev. | 0.70 | 1.15 | 0.53 | 1.43 | 4.63 | 0.78 |
| Nitrite - T0 | Mean | 1.04 | 1.10 | 1.04 | 0.81 | 0.94 | 1.28 |
| ( µM) | Std. Dev. | 0.44 | 0.55 | 0.42 | 0.27 | 0.54 | 0.70 |
| Nitrification - Nitrate | Mean | 1.72 | -1.23 | 6.73 | -2.77 | -15.37 | -5.31 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 10.67 | 4.96 | 9.04 | 9.46 | 22.40 | 14.35 |
| Nitrification - Nitrite | Mean | -0.30 | -3.81 | 0.55 | -0.34 | -1.02 | -1.44 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.71 | 3.99 | 2.94 | 1.95 | 2.29 | 7.42 |

**August**

**Redox Potential**

The redox potentials in August ranged from -400 to 190 mV. The highest readings were observed in Block 1 and the lowest readings were in Block 3. There was a trend of higher redox potentials in wrack-covered areas, but these differences were not statistically significant ($p > 0.05$).

Table 6 illustrates that the main effect of Block was significant ($p = 0.0001$) as was the main effect of Flood ($p = 0.0001$). Additionally, the Block*Veg interaction ($p = 0.0099$) and Block*Flood interaction ($p = 0.0235$) were significant.

The Block effect illustrates the differences in the redox potentials among the three blocks. The redox potentials in Block 1 are significantly higher than the redox potential measured in Blocks 2 and 3. The redox potentials in Blocks 2 and 3 were statistically similar (Table 6).

The Flood effect describes how the **F** plots, with a mean Eh of 35 mV, and the **C** plots, with a mean Eh of 36 mV, have statistically similar redox potentials. The redox potentials in the **BC** plots, with a mean of -72 mV, were significantly lower ($p < 0.05$) than the redox potentials observed in the **F** and **C** plots (Table 6).

The Block*Flood interaction is a consequence of Blocks 2 and 3 having similar patterns of redox potential that differed from the pattern seen in Block 1. Specifically, the lowest redox potentials were observed in the **BC** plots. The highest redox potentials in Blocks 1 and 3 were measured in the **C** plots, but the highest redox potentials in Block 2 were measured in the **F** plots (Table 7).

The Block*Veg interaction results from the fact that Blocks 1 and 2 were similar in that they had higher redox potentials in the wrack-covered sections and lower redox potentials in the vegetated sections. However, Block 3 had higher redox potentials in the vegetated sections and lower redox potentials in the wrack-covered sections (Table 8).

**Bulk Density**

Bulk density ranged in value from 0.087 to 0.358 g $cm^{-3}$. The main effects of Block ($p = 0.0007$), Flood ($p = 0.0303$), and Veg ($p = 0.0056$) were significant.

The Block effect illustrates how the bulk densities differed between the blocks (Table 6). Block 2 had significantly higher ($p < 0.05$) bulk densities than Block 3. Block 1 had bulk densities that were statistically similar to Block 2 and Block 3.

The flooding treaatment affected the bulk density of the soil (Table 6). The **BC** plots had significantly higher bulk densities than the **C** plots ($p < 0.05$). The **F** plots had bulk densities that were statistically similar to both the **BC** plots and **C** plots.

The vegetation also had an effect on the bulk densities (Table 6). The vegetated areas had significantly higher ($p < 0.05$) bulk densities than the wrack-covered areas.

**Percent Moisture**

The percent moisture of the soil ranged from 65.3 to 89.0 percent. The main effects of Block ($p = 0.0050$), Flood ($p = 0.0144$), and Veg ($p = 0.0006$) were significant. The interaction effects of Block*Flood ($p = 0.0005$) and Block*Flood*Veg ($p = 0.0018$) were also significant.

The percent moistures of Block 3 were significantly higher ($p < 0.05$) than the values observed in Block 2. The percent moistures of Block 1 were statistically similar to the values obtained in Block 2 and Block 3 (Table 6).

The flooding treatment also significantly affected the measured percent moistures of the soil (Table 6). The **C** plots had significantly higher ($p < 0.05$) percent moistures than the **BC** plots. The percent moistures measured in the **F** plots were statistically similar to the values obtained in the **C** and **BC** plots.

The presence of wrack significantly affects the percent moisture of the soil (Table

6). The soil under wrack-covered areas had higher ($p < 0.05$) percent moistures than the soil in the vegetated sections.

The interaction between the Block and Flood treatments illustrates the highest percent moistures found in the **F** plots and the lowest in the **BC** plots in Blocks 2 and 3. Block 1 differed by having the highest percent moistures in the **C** plot and the lowest in the **F** plot (Table 7). Furthermore, the magnitude of the difference of the percent moisture measurements varied between the Flood and Block conditions.

The Block*Flood*Veg interaction is a consequence of the wrack-covered sections having higher percent moistures than the vegetated areas in the **BC** and **F** plots in Blocks 1 and 3 and in the **BC** and **C** plots in Block 2. The vegetated sections had higher percent moisture measurements in the **C** plots in Blocks 1 and 3 and in the **F** plot in Block 2 than were measured in wrack-covered areas. In addition, the magnitude of the difference varied between the flooding conditions and the Blocks.

**$NO_3^-$ and $NO_2^-$ Concentrations**

Tables 6 - 9 illustrate the mean $NO_3^-$ and $NO_2^-$ concentrations for the main effects and the interaction effects. The $NO_3^-$ concentrations ranged from 0.23 to 13.19 µM. The $NO_2^-$ concentrations ranged from 0.05 to 0.75 µM. The main effects of Block ($p = 0.0003$) and Flood ($p = 0.0035$) were significant for $NO_3^-$ concentrations as were the interaction effects of Block*Flood ($p = 0.0020$) and Block*Flood*Veg ($p = 0.0028$). The main effects of Block ($p = 0.0015$), Flood ($p = 0.0077$) and Veg ($p = 0.0334$) were significant on $NO_2^-$ concentrations as were the interaction effects of Block*Flood ($p = 0.0231$), Block*Veg ($p = 0.0061$) and Block*Flood*Veg ($p = 0.0025$).

The Block effect results from Blocks 1 and 3 having significantly higher ($p < 0.05$) $NO_3^-$ concentrations than Block 2. Blocks 1 and 3 had similar $NO_3^-$ concentrations (Table 6).

The Flood effect illustrates how the **C** plots have statistically higher ($p < 0.05$) $NO_3^-$ concentrations than the **F** plots. The **BC** plots had concentrations similar to those found in the **C** and **F** plots (Table 6).

The Block*Flood effect is a consequence of several factors. The **C** plots had the highest $NO_3^-$ concentrations, and the **F** plots had the lowest $NO_3^-$ concentrations in Blocks 1 and 2. In Block 3, the highest $NO_3^-$ concentrations were found in the **BC** plot and the lowest in the **F** plot (Table 7). The magnitude of the difference in $NO_3^-$ concentrations between the flooding treatments varied greatly between Blocks.

The Block*Flood*Veg interaction results from wrack-covered sections having higher $NO_3^-$ concentrations than vegetated areas in all experimental areas except the **C** plot in Block 1 and the **BC** and **F** plots in Block 3. Also, the magnitude of the difference between vegetated and wrack-covered areas varied between the flooding treatments which in turn varied among the Blocks.

For $NO_2^-$, the Block effect results from Block 3 having significantly higher ($p < 0.05$) concentrations than Blocks 1 and 2. The concentrations measured in Blocks 1 and 2 were similar (Table 6).

The Flood effect is a consequence of **BC** plots having significantly higher ($p < 0.05$) $NO_2^-$ levels than **F** plots. The **C** plots had $NO_2^-$ concentrations similar to those measured in **BC** and **F** plots (Table 6).

The Veg effect results from vegetated sections having significantly higher ($p < 0.05$) $NO_2^-$ concentrations than areas covered with wrack (Table 6).

The interaction of Block*Flood is a consequence of the **C** plots having the highest and **F** plots having the lowest $NO_2^-$ concentrations in Blocks 2 and 3, while the **BC** plot had the highest $NO_2^-$ concentrations, and the **C** plot had the lowest. Furthermore, the magnitude of the difference in $NO_2^-$ concentrations between flooding treatments varied greatly among the blocks (Table 7).

The Block*Veg interaction results from vegetated areas having statistically higher ($p < 0.05$) $NO_2^-$ concentrations than wrack-covered sections in Blocks 2 and 3. Wrack-covered areas have significantly higher $NO_2^-$ concentrations than vegetated areas in Block 1 (Table 8). In addition, the magnitude of the difference in $NO_2^-$ concentrations between wrack-covered and vegetated areas varied greatly among the Blocks.

The Block*Flood*Veg interaction is a consequence of various factors. First, the vegetated sections had higher $NO_2^-$ concentrations than wrack-covered areas except in the **BC** plot in Block 1. Furthermore, the **C** plots had the highest $NO_2^-$ concentrations in Blocks 2 and 3 while the **BC** plot had the highest $NO_2^-$ concentrations in Block 1. Finally, the magnitude of the difference in $NO_2^-$ concentrations varied greatly (1) between the vegetation treatments between the flooding conditions and (2) between the flooding conditions between the Blocks.

**Nitrification**

Nitrification rates estimated using $NO_3^-$ ranged from a negative rate of -37.02 up to 49.42 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$. The main effect of Block ($p = 0.0392$) was significant as was the Block*Flood*Veg interaction effect ($p = 0.0081$).

Nitrification rates were highest in Block 1 and were significantly higher than the rates measured in Block 2, which had the lowest rate ($p < 0.05$). The rates of nitrification in Block 3 were statistically similar to the rates measured in both Blocks 1 and 2 (Table 6).

The Block*Flood*Veg interaction results from the complex interaction the three main effects have on nitrification rates. Higher rates were measured in vegetated sections in **BC** and **F** plots in Block 1, **BC** and **C** plots in Block 2, and in **C** and **F** plots in Block 3. The other areas—the **C** plot in Block 1, the **F** plot in Block 2, and the **BC** plot in Block 3-

all had higher nitrification rates in wrack-covered sections than in vegetated areas. Besides the varying locations, the magnitude of the difference in rates between vegetated and wrack-covered sections varied greatly between flooding conditions and between blocks.

Using $NO_2^-$ concentrations resulted in nitrification rates ranging from a low of -3.54 up to 5.58 µmol $NO_2^-$ $m^{-2}$ $h^{-1}$. No significant main or interaction effects were observed (Table 6).

**Denitrification**

The rates of denitrification ranged from -4.9 to 75.8 µmol $m^{-2}$ $h^{-1}$. The main effects of Block ($p = 0.0034$) and Veg ($p = 0.0001$) were significant (Table 6). Likewise, the interaction effects of Block*Flood ($p = 0.0001$), Block*Veg ($p = 0.0018$), and Block*Flood*Veg ($p = 0.0001$) were also significant (Table 6).

Denitrification rates in Blocks 1 and 3 were similar but significantly higher ($p < 0.05$) than the rates observed in Block 2 (Table 6). The mean rates of denitrification in Blocks 1 and 3 were 10.6 and 10.1 µmol $m^{-2}$ $h^{-1}$ while the mean rate in Block 2 was only 1.3 µmol $m^{-2}$ $h^{-1}$ (Table 6).

Denitrification rates were significantly higher ($p < 0.05$) in wrack-covered areas than in vegetated sections (Table 6). The mean rate in wrack-covered sections was 14.8 µmol $m^{-2}$ $h^{-1}$ while the mean rate in vegetated areas was -0.2 µmol $m^{-2}$ $h^{-1}$ (Table 6).

The Block*Flood interaction results from no consistent pattern of higher rates being observed in any Block or Flood condition. In Block 1, the **C** plot had the highest rates and the **BC** plot had the lowest. The rates in Block 2 were highest in the **F** plot while lowest in the **C** plot. Finally, Block 3 had its highest rates in the **BC** plot and its lowest in the **F** plot. In addition, the difference in magnitude between the rates varied among the Flood and Block treatments (Table 7).

An interaction between Block and Veg is a consequence of the Block and Vegetation treatments acting together to affect denitrification rates. Although the wrack-covered sections always had higher rates, the magnitude of the difference in the rates between the vegetated and wrack-covered areas differs greatly among the Vegetation and Block treatments (Table 8).

The Block*Flood*Veg results from the complex nature of the way in which these treatments interact. Denitrification rates were higher in wrack-covered sections than in vegetated areas except in the **C** plot in Block 2 that had the highest mean denitrification rate of any vegetated area. The wrack-covered areas in the **C** and **F** plots in Block 1 and the **BC** plot in Block 3 had significantly higher denitrification rates than any of the other wrack-covered or vegetated areas. The interaction also derives from the differences in magnitude between the Vegetated and Wrack sections in the different Blocks and Flood conditions.

Table 6: The means, standard deviationss, and Tukey groupings for August's data.

| Variable | Measure of: | Block 1 | Block 2 | Block 3 | Flood Border | Flood Control | Flood Flood | Vegetation Juncus | Vegetation Wrack |
|---|---|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 103 | -6 | -97 | -72 | 36 | 35 | -13 | 12 |
| ( mV ) | Std. Dev. | 70.1 | 71.8 | 127.6 | 140.4 | 105.1 | 93.2 | 109.9 | 136.6 |
| | Tukey Grouping | A | B | C | D | E | E | G | G |
| Bulk Density | Mean | 0.149 | 0.171 | 0.120 | 0.164 | 0.130 | 0.146 | 0.161 | 0.132 |
| ( g cm^-1) | Std. Dev. | 0.058 | 0.038 | 0.031 | 0.062 | 0.041 | 0.034 | 0.059 | 0.029 |
| | Tukey Grouping | A/B | A | B | D | E | D/E | G | H |
| Percent Moisture | Mean | 83.9 | 82.9 | 86.0 | 83.1 | 85.8 | 83.8 | 82.9 | 85.6 |
| ( % ) | Std. Dev. | 5.1 | 2.3 | 4.1 | 5.5 | 2.7 | 3.4 | 5.3 | 1.8 |
| | Tukey Grouping | A/B | A | B | D | E | D/E | G | H |
| Nitrate - T0 | Mean | 4.26 | 0.95 | 3.73 | 2.98 | 4.32 | 1.48 | 3.24 | 2.66 |
| ( µM ) | Std. Dev. | 4.14 | 0.50 | 3.44 | 3.73 | 4.02 | 0.77 | 4.05 | 2.54 |
| | Tukey Grouping | A | B | A | D/E | E | D | G | G |
| Nitrite - T0 | Mean | 0.27 | 0.25 | 0.38 | 0.36 | 0.30 | 0.23 | 0.33 | 0.27 |
| ( µM ) | Std. Dev. | 0.19 | 0.11 | 0.15 | 0.20 | 0.14 | 0.10 | 0.14 | 0.17 |
| | Tukey Grouping | A | A | B | D | D/E | E | G | H |
| Nitrification - Nitrate | Mean | 11.01 | -1.13 | -0.46 | -0.48 | 5.51 | 5.03 | 4.21 | 2.35 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 22.04 | 6.21 | 19.49 | 15.56 | 19.23 | 19.09 | 18.94 | 17.03 |
| | Tukey Grouping | A | A | A | D | D | D | G | G |
| Nitrification - Nitrite | Mean | 0.77 | -0.02 | 0.45 | 0.25 | 0.27 | 0.68 | 0.43 | 0.37 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.63 | 0.52 | 1.79 | 1.71 | 0.91 | 1.61 | 1.76 | 1.06 |
| | Tukey Grouping | A | A | A | D | D | D | G | G |
| Denitrification | Mean | 10.56 | 1.28 | 10.14 | 9.14 | 7.23 | 5.60 | -0.19 | 14.84 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 17.83 | 3.68 | 24.10 | 24.57 | 14.67 | 12.04 | 1.82 | 22.67 |
| | Tukey Grouping | A | B | A | D | D | D | G | H |

Note: Tukey goupings are labelled by Treatment. Block uses 'A', 'B', and 'C'. Flood uses 'D', 'E', and 'F'. Vegetation uses 'G' and 'H'. Measurements with differing groupings indicate a significant difference ($p < 0.05$) between the means.

Table 7: The means and standard deviations for the B*F interaction for August's data.

| Variable | Measure of: | Block 1 Border | Block 1 Control | Block 1 Flood | Block 2 Border | Block 2 Control | Block 2 Flood | Block 3 Border | Block 3 Control | Block 3 Flood |
|---|---|---|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | -15 | 154 | 138 | -15 | -4 | 1 | -215 | -43 | -33 |
| ( mV ) | Std. Dev. | 26.7 | 35.6 | 27.9 | 84.6 | 82.6 | 58.4 | 146.9 | 56.5 | 74.5 |
| Bulk Density | Mean | 0.190 | 0.118 | 0.137 | 0.181 | 0.169 | 0.164 | 0.120 | 0.101 | 0.137 |
| ( g cm^-1) | Std. Dev. | 0.085 | 0.016 | 0.025 | 0.046 | 0.048 | 0.021 | 0.006 | 0.011 | 0.047 |
| Percent Moisture | Mean | 80.1 | 86.2 | 85.2 | 82.1 | 82.7 | 83.8 | 87.1 | 88.4 | 82.4 |
| ( % ) | Std. Dev. | 7.75 | 1.00 | 1.38 | 3.19 | 2.14 | 1.29 | 0.69 | 0.57 | 5.65 |
| Nitrate - T0 | Mean | 2.53 | 8.18 | 1.62 | 1.02 | 1.16 | 0.67 | 5.38 | 3.63 | 2.17 |
| ( µM) | Std. Dev. | 2.98 | 4.11 | 0.35 | 0.68 | 0.40 | 0.29 | 5.12 | 2.75 | 0.56 |
| Nitrite - T0 | Mean | 0.40 | 0.18 | 0.23 | 0.24 | 0.30 | 0.20 | 0.43 | 0.43 | 0.28 |
| ( µM) | Std. Dev. | 0.27 | 0.08 | 0.04 | 0.08 | 0.07 | 0.15 | 0.19 | 0.12 | 0.08 |
| Nitrification - Nitrate | Mean | -2.02 | 18.26 | 16.79 | -2.04 | 1.42 | -2.79 | 2.60 | -4.88 | 0.28 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 3.46 | 23.51 | 27.93 | 9.45 | 4.36 | 3.27 | 26.55 | 19.00 | 11.95 |
| Nitrification - Nitrite | Mean | -0.14 | 0.45 | 1.99 | 0.13 | -0.03 | -0.16 | 0.76 | 0.39 | 0.20 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 0.32 | 0.98 | 2.26 | 0.42 | 0.66 | 0.50 | 3.03 | 1.12 | 0.50 |
| Denitrification | Mean | -2.00 | 19.08 | 14.59 | 1.15 | 1.08 | 1.61 | 28.27 | 1.53 | 0.61 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.60 | 21.60 | 17.76 | 3.73 | 1.94 | 5.32 | 37.03 | 2.87 | 1.76 |

Table 8: The means and standard deviations for the B*V interaction for August's data.

| Variable | Measure of: | Juncus Block 1 | Juncus Block 2 | Juncus Block 3 | Wrack Block 1 | Wrack Block 2 | Wrack Block 3 |
|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 91 | -52 | -78 | 114 | 40 | -117 |
| ( mV ) | Std. Dev. | 74.6 | 72.1 | 99.1 | 67.6 | 31.3 | 154.7 |
| Bulk Density | Mean | 0.166 | 0.186 | 0.132 | 0.132 | 0.157 | 0.107 |
| ( g cm^-1) | Std. Dev. | 0.079 | 0.042 | 0.039 | 0.016 | 0.030 | 0.013 |
| Percent Moisture | Mean | 82.5 | 81.8 | 84.3 | 85.2 | 84.0 | 87.6 |
| ( % ) | Std. Dev. | 7.07 | 2.70 | 5.33 | 1.14 | 1.22 | 0.73 |
| Nitrate - T0 | Mean | 4.50 | 0.64 | 4.57 | 3.99 | 1.25 | 2.88 |
| ( µM) | Std. Dev. | 4.88 | 0.28 | 4.25 | 3.43 | 0.51 | 2.35 |
| Nitrite - T0 | Mean | 0.23 | 0.31 | 0.45 | 0.32 | 0.18 | 0.3 |
| ( µM) | Std. Dev. | 0.03 | 0.09 | 0.17 | 0.27 | 0.09 | 0.08 |
| Nitrification - Nitrate | Mean | 10.12 | 0.67 | 1.52 | 11.90 | -2.94 | -2.45 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 24.28 | 6.45 | 22.14 | 21.00 | 5.74 | 17.73 |
| Nitrification - Nitrite | Mean | 1.40 | -0.24 | 0.12 | 0.13 | 0.21 | 0.78 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.11 | 0.56 | 1.90 | 0.51 | 0.38 | 1.17 |
| Denitrification | Mean | -0.25 | 0.19 | -0.51 | 21.36 | 2.37 | 20.79 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.27 | 2.10 | 0.92 | 20.19 | 4.67 | 31.28 |

Table 9: The means and standard deviations for the F*V interaction for August's data.

| | | Juncus | | | Wrack | | |
|---|---|---|---|---|---|---|---|
| Variable | Measure of: | Border | Control | Flood | Border | Control | Flood |
| Redox Potential | Mean | -71 | 18 | 14 | -72 | 53 | 56 |
| ( mV ) | Std. Dev. | 98.8 | 124.1 | 91.4 | 179.2 | 85.7 | 95.6 |
| Bulk Density | Mean | 0.191 | 0.130 | 0.163 | 0.137 | 0.129 | 0.130 |
| ( g cm^-1) | Std. Dev. | 0.079 | 0.043 | 0.033 | 0.016 | 0.041 | 0.027 |
| Percent Moisture | Mean | 80.8 | 85.6 | 82.2 | 85.4 | 86.0 | 85.5 |
| ( % ) | Std. Dev. | 7.00 | 3.43 | 3.86 | 1.68 | 2.00 | 2.01 |
| Nitrate - T0 | Mean | 3.38 | 4.89 | 1.44 | 2.58 | 3.76 | 1.52 |
| ( µM ) | Std. Dev. | 4.85 | 4.71 | 0.93 | 2.38 | 3.39 | 0.60 |
| Nitrite - T0 | Mean | 0.35 | 0.36 | 0.28 | 0.36 | 0.25 | 0.19 |
| ( µM ) | Std. Dev. | 0.19 | 0.15 | 0.07 | 0.23 | 0.11 | 0.17 |
| Nitrification - Nitrate | Mean | 0.06 | 1.26 | 10.97 | -1.02 | 9.29 | -1.66 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 21.06 | 0.40 | 24.09 | 8.38 | 26.24 | 8.57 |
| Nitrification - Nitrite | Mean | 0.19 | -0.00 | 1.09 | 0.32 | 0.54 | 0.26 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.87 | 0.98 | 2.20 | 1.65 | 0.78 | 0.49 |
| Denitrification | Mean | -1.50 | 1.08 | -0.14 | 19.79 | 13.38 | 11.34 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 0.64 | 1.82 | 1.80 | 32.05 | 19.20 | 15.19 |

## September

### Redox Potential

For the September redox potentials, ranging from 50 to 340 mV, the significant effects were Block ($p = 0.0001$), Flood ($p = 0.0001$), and a Block*Flood interaction ($p = 0.0001$).

Block 1 had significantly higher redox potentials than either Block 2 or Block 3 ($p < 0.05$). The redox potentials in Block 3 were significantly similar to the redox potentials observed in Block 2 (Table 10).

The Flood effect is a consequence of the **C** plots having significantly higher ($p < 0.05$) redox potentials than either the **BC** plots or the **F** plots (Table 10). The **BC** and **F** plots had statistically similar redox potentials.

The Block*Flood interaction describes how the magnitude of the difference in measurements varied among in the Blocks. In Block 1, the effects of the different flooding conditions were much greater than they were in Blocks 2 and 3 (Table 11).

**Bulk Density**

Bulk densities ranged in value from 0.046 to 0.143 g $cm^{-3}$. Only the main effect of Block was significant ($p = 0.0001$).

The bulk densities in Block 2 were significantly higher ($p < 0.05$) than the bulk densities measured in either Block 1 or Block 3 (Table 10). The bulk densities in Block 1 were significantly higher than in Block 3 ($p < 0.05$).

**Percent Moisture**

The percent moisture measurements were higher in September than in August as they ranged from 78.1 to 91.8 percent water. The main effect of Block was significant ($p = 0.0001$). In addition, the interaction effects of Block*Flood ($p = 0.0174$) and Block*Flood*Veg ($p = 0.0314$) were significant.

The location from which the samples were taken affected the percent moisture (Table 10). The percent moisture in Block 3 was higher ($p < 0.05$) than the values observed in either Block 1 or Block 2. The percent moisture in Block 1 was statistically similar to the values measured in Block 2.

Although the **C** plots always had the highest Eh values and the **BC** plots had the lowest, the Block*Flood interaction is a consequence of the magnitude of the difference among the mean redox potentials measured between different blocks and flooding treatments. These differences were large between Block 1 and Blocks 2 and 3, while rather small between Blocks 2 and 3. Similarly, the magnitude of the difference between flooding treatments within the same Block varied greatly—being large in Block 1 and small in Blocks 2 and 3 (Table 11).

The Block*Flood*Veg interaction results from the complex interaction the three main effects have on percent moistures. The percent moistures of the soil in Blocks 1 and 2 exhibit a similar trend. The soil in the vegetated sections of the **BC** and **F** plots has higher percent moistures than the wrack-covered areas, but the situation is reversed in the **C** plot where higher percent moistures are seen in vegetated areas than in wrack-covered sections. The pattern of percent moistures reverses in Block 3 where vegetated sections of the **BC** and **F** plots have higher percent moistures than wrack. The **C** plot in Block 3 has higher percent moistures in areas covered by wrack than the soil in vegetated sections. As before, the magnitude of the difference between vegetated and wrack-covered areas varied among flooding and Block treatments.

**$NO_3^-$ and $NO_2^-$ Concentrations**

The $NO_3^-$ concentrations ranged from undetectable to 13.78 µM. The $NO_2^-$ concentrations ranged from 0.30 to 2.02 µM. The main effects of Block ($p = 0.0001$) and Veg ($p = 0.0055$) were significant for $NO_3^-$ concentrations, whereas only the main effect of Block ($p = 0.0001$) was significant for $NO_2^-$ concentrations.

The Block effect results from Block 3 having significantly higher $NO_3^-$ concentrations than either Blocks 1 or 2 (Table 10). Concentrations in Block 1 are similar to those measured in Block 2.

The Veg effect is a consequence of the wrack-covered sections having significantly higher ($p < 0.05$) $NO_3^-$ concentrations than vegetated areas (Table 10).

The Block effect on $NO_2^-$ concentrations results from Blocks 2 and 3 having significantly higher $NO_2^-$ concentrations than found in Block 1 (Table 10).

**Nitrification**

Nitrification rates estimated using $NO_3^-$ ranged from a negative rate of -46.23 up to 34.20 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$. Only the main effect of Veg was significant ($p = 0.0072$). The Veg effect reflects how wrack-covered areas had significantly higher ($p < 0.05$) rates than vegetated sections (Table 10). Using $NO_2^-$, nitrification rates ranged from a low of -9.21 up to 15.26 µmol $NO_2^-$ $m^{-2}$ $h^{-1}$. None of the main effects or interaction effects were significant.

**Denitrification**

Denitrification rates ranged from -7.7 to 63.1 µmol $m^{-2}$ $h^{-1}$. The main effects of Block ($p = 0.0049$) and Veg ($p = 0.0009$) were significant as was the interaction effect of Block*Veg ($p = 0.0174$).

The main effect of Block is a consequence of Block 1 having significantly higher ($p < 0.05$) rates than Block 2 (Table 10). Block 3, however, had rates statistically similar to Blocks 1 and 2.

The rates in wrack-covered areas were significantly higher ($p < 0.05$) than in the vegetated areas (Table 10).

The Block*Veg interaction results from the fact that although denitrification rates were always higher in wrack-covered sections than in vegetated areas, the magnitude of the difference between the rates in wrack versus vegetated sections varied greatly between the blocks (Table 12).

Table 10: The means, standard deviations, and Tukey groupings for September's data.

| Variable | Measure of: | Block 1 | Block 2 | Block 3 | Flood Border | Flood Control | Flood Flood | Vegetation Juncus | Vegetation Wrack |
|---|---|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 135 | 76 | 84 | 76 | 130 | 88 | 97 | 100 |
| ( mV ) | Std. Dev. | 75.3 | 9.2 | 10.1 | 9.7 | 75.2 | 24.9 | 33.1 | 64.6 |
| | Tukey Grouping | A | B | B | D | E | D | G | G |
| Bulk Density | Mean | 0.067 | 0.084 | 0.054 | 0.069 | 0.071 | 0.065 | 0.070 | 0.067 |
| ( g cm^-1) | Std. Dev. | 0.007 | 0.024 | 0.006 | 0.024 | 0.019 | 0.013 | 0.022 | 0.016 |
| | Tukey Grouping | A | B | C | D | D | D | G | G |
| Percent Moisture | Mean | 86.2 | 85.0 | 89.2 | 86.8 | 86.5 | 87.0 | 86.6 | 87.0 |
| ( % ) | Std. Dev. | 0.94 | 3.07 | 1.27 | 3.26 | 3.06 | 1.27 | 2.85 | 2.45 |
| | Tukey Grouping | A | A | B | D | D | D | G | G |
| Nitrate - T0 | Mean | 1.44 | 1.10 | 3.70 | 2.32 | 2.04 | 1.88 | 1.42 | 2.74 |
| ( µM ) | Std. Dev. | 0.65 | 1.14 | 3.12 | 3.59 | 1.14 | 1.18 | 1.18 | 2.82 |
| | Tukey Grouping | A | A | B | D | D | D | G | H |
| Nitrite - T0 | Mean | 0.54 | 1.12 | 0.99 | 0.90 | 0.97 | 0.77 | 0.94 | 0.82 |
| ( µM ) | Std. Dev. | 0.14 | 0.29 | 0.47 | 0.38 | 0.47 | 0.35 | 0.45 | 0.36 |
| | Tukey Grouping | A | B | B | D | D | D | G | G |
| Nitrification - Nitrate | Mean | -0.13 | 4.11 | 8.57 | 7.52 | 1.40 | 3.63 | 0.18 | 8.19 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 14.88 | 7.45 | 10.82 | 11.30 | 14.35 | 8.94 | 11.81 | 10.53 |
| | Tukey Grouping | A | A/B | B | D | D | D | G | H |
| Nitrification - Nitrite | Mean | 0.91 | 0.91 | 0.81 | 0.78 | 1.57 | 0.28 | 0.92 | 0.83 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.34 | 4.39 | 4.64 | 2.33 | 4.11 | 4.40 | 3.99 | 3.45 |
| | Tukey Grouping | A | A | A | D | D | D | G | G |
| Denitrification | Mean | 13.92 | 2.44 | 5.86 | 5.09 | 10.24 | 6.89 | 2.45 | 12.36 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 18.93 | 7.45 | 8.45 | 15.80 | 14.53 | 9.14 | 4.96 | 17.02 |
| | Tukey Grouping | A | B | A/B | D | D | D | G | H |

Note: Tukey goupings are labelled by Treatment. Block uses 'A', 'B', and 'C'. Flood uses 'D', 'E', and 'F'. Vegetation uses 'G' and 'H'. Measurements with differing groupings indicate a significant difference ($p < 0.05$) between the means.

Table 11: The means and standard deviations for the B*F interaction for September's data.

| Variable | Measure of: | Block 1 Border | Block 1 Control | Block 1 Flood | Block 2 Border | Block 2 Control | Block 2 Flood | Block 3 Border | Block 3 Control | Block 3 Flood |
|---|---|---|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 82 | 221 | 103 | 70 | 79 | 78 | 78 | 91 | 83 |
| ( mV ) | Std. Dev. | 6.8 | 64.2 | 40.3 | 13.0 | 6.7 | 4.2 | 4.2 | 14.3 | 4.1 |
| Bulk Density | Mean | 0.067 | 0.070 | 0.065 | 0.085 | 0.092 | 0.074 | 0.054 | 0.053 | 0.057 |
| ( g cm^-1) | Std. Dev. | 0.008 | 0.007 | 0.006 | 0.037 | 0.014 | 0.016 | 0.005 | 0.006 | 0.007 |
| Percent Moisture | Mean | 85.7 | 86.2 | 86.9 | 84.9 | 83.7 | 86.3 | 90.0 | 89.7 | 87.8 |
| ( % ) | Std. Dev. | 0.80 | 1.14 | 0.42 | 3.97 | 2.97 | 11.92 | 1.10 | 0.70 | 0.53 |
| Nitrate - T0 | Mean | 1.16 | 1.68 | 1.49 | 0.52 | 1.36 | 1.43 | 5.29 | 3.07 | 2.73 |
| ( µM ) | Std. Dev. | 0.51 | 0.48 | 0.89 | 0.92 | 0.83 | 1.51 | 5.16 | 1.22 | 0.59 |
| Nitrite - T0 | Mean | 0.60 | 0.48 | 0.53 | 1.05 | 1.24 | 1.07 | 1.04 | 1.20 | 0.72 |
| ( µM ) | Std. Dev. | 0.19 | 0.10 | 0.11 | 0.09 | 0.24 | 0.45 | 0.55 | 0.51 | 0.18 |
| Nitrification - Nitrate | Mean | 2.53 | -3.67 | 0.75 | 8.43 | 0.50 | 3.39 | 11.61 | 7.36 | 6.74 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 13.98 | 22.70 | 4.20 | 10.24 | 2.58 | 6.20 | 9.10 | 10.20 | 13.94 |
| Nitrification - Nitrite | Mean | 0.68 | 0.74 | 1.30 | -0.24 | 1.80 | 1.17 | 1.89 | 2.16 | -1.61 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.39 | 1.06 | 1.65 | 2.19 | 3.02 | 7.00 | 2.99 | 6.77 | 2.78 |
| Denitrification | Mean | 16.64 | 18.86 | 6.27 | -0.80 | 6.76 | 1.35 | -0.58 | 5.09 | 13.06 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 23.73 | 22.53 | 6.26 | 2.41 | 7.52 | 9.49 | 6.29 | 4.29 | 8.49 |

Table 12: The means and standard deviations for thee B*V interaction for September's data.

| Variable | Measure of: | Juncus Block 1 | Juncus Block 2 | Juncus Block 3 | Wrack Block 1 | Wrack Block 2 | Wrack Block 3 |
|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 122 | 81 | 88 | 148 | 71 | 80 |
| ( mV ) | Std. Dev. | 47.7 | 4.6 | 12.0 | 96.8 | 10.1 | 6.1 |
| Bulk Density | Mean | 0.067 | 0.089 | 0.054 | 0.068 | 0.078 | 0.055 |
| ( g cm^-1) | Std. Dev. | 0.007 | 0.028 | 0.006 | 0.007 | 0.020 | 0.007 |
| Percent Moisture | Mean | 86.1 | 84.4 | 89.4 | 86.4 | 85.6 | 88.9 |
| ( % ) | Std. Dev. | 1.08 | 3.02 | 1.22 | 0.82 | 3.18 | 1.35 |
| Nitrate - T0 | Mean | 1.17 | 0.63 | 2.46 | 1.72 | 1.57 | 4.94 |
| ( µM) | Std. Dev. | 0.64 | 0.96 | 1.09 | 0.57 | 1.16 | 4.01 |
| Nitrite - T0 | Mean | 0.55 | 1.16 | 1.10 | 0.53 | 1.08 | 0.87 |
| ( µM) | Std. Dev. | 0.17 | 0.20 | 0.57 | 0.12 | 0.37 | 0.32 |
| Nitrification - Nitrate | Mean | -7.88 | 1.89 | 6.43 | 7.53 | 6.33 | 10.71 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 16.09 | 3.23 | 8.11 | 8.92 | 9.82 | 13.14 |
| Nitrification - Nitrite | Mean | 1.04 | 0.51 | 1.19 | 0.77 | 1.30 | 0.43 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.21 | 2.63 | 6.56 | 1.51 | 5.80 | 1.52 |
| Denitrification | Mean | 3.26 | -0.70 | 4.79 | 24.59 | 5.57 | 6.92 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 3.77 | 1.72 | 6.69 | 22.16 | 9.64 | 10.21 |

Table 13: The means and standard deviations for the F*V interaction for September's data.

| Variable | Measure of: | Juncus Border | Juncus Control | Juncus Flood | Wrack Border | Wrack Control | Wrack Flood |
|---|---|---|---|---|---|---|---|
| Redox Potential | Mean | 82 | 124 | 85 | 71 | 137 | 91 |
| ( mV ) | Std. Dev. | 5.6 | 46.9 | 9.4 | 10.2 | 98.6 | 34.7 |
| Bulk Density | Mean | 0.076 | 0.070 | 0.063 | 0.061 | 0.073 | 0.067 |
| ( g cm^-1) | Std. Dev. | 0.032 | 0.015 | 0.015 | 0.010 | 0.023 | 0.010 |
| Percent Moisture | Mean | 85.9 | 87.0 | 86.8 | 87.8 | 86.0 | 87.1 |
| ( % ) | Std. Dev. | 4.24 | 2.12 | 1.77 | 1.68 | 3.85 | 0.50 |
| Nitrate - T0 | Mean | 1.02 | 1.86 | 1.38 | 3.63 | 2.22 | 2.38 |
| ( µM) | Std. Dev. | 1.13 | 1.21 | 1.16 | 4.72 | 1.11 | 1.02 |
| Nitrite - T0 | Mean | 1.01 | 0.99 | 0.82 | 0.79 | 0.96 | 0.72 |
| ( µM) | Std. Dev. | 0.47 | 0.53 | 0.36 | 0.26 | 0.44 | 0.36 |
| Nitrification - Nitrate | Mean | 0.98 | -3.35 | 2.90 | 14.07 | 6.14 | 4.35 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 9.25 | 18.18 | 3.82 | 9.45 | 7.51 | 12.42 |
| Nitrification - Nitrite | Mean | 0.79 | 2.99 | -1.03 | 0.76 | 0.14 | 1.60 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.96 | 5.11 | 2.80 | 1.67 | 2.29 | 5.43 |
| Denitrification | Mean | -0.28 | 3.07 | 4.55 | 10.45 | 17.40 | 9.23 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 4.49 | 4.65 | 4.93 | 21.11 | 17.65 | 11.88 |

**Short-Term Drying Experiment:**

In October, the percent moisture of the soil was significantly affected by the main effect of wetness. The other rates and values were not statistically affected by the treatment (Table 14).

**Bulk Density**

The bulk density of the samples ranged from 0.050 to 0.060 g $cm^{-3}$. The bulk densities were not affected by drying (Table 14).

**Percent Moisture**

The percent moisture of the soil samples ranged from 87.2 to 90.2 percent water. The values were significantly higher ($p < 0.05$) in the wet treatment than in the dry treatment (Table 14).

**Nitrification**

Nitrification rates estimated using $NO_3^-$ ranged from -8.77 to 5.91 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$. The rates were statistically similar in wet and dry treatments. Using $NO_2^-$, nitrification rates ranged from -3.52 to 3.79 µmol $NO_2^-$ $m^{-2}$ $h^{-1}$. The rates were statistically similar in wet and dry treatments (Table 14).

**Denitrification**

The values for denitrification ranged from -6.4 to 2.3 µmol $N_2O$ $m^{-2}$ $h^{-1}$. The one positive rate occurred in the wet condition. Although the means of the two treatments appear quite different, there was no significant difference between wet and dry treatments (Table 14).

Table 14: The means, standard deviations and Tukey groupings for October's data.

| Variable | Measure of: | Wet | Dry |
|---|---|---|---|
| Bulk Density | Mean | 0.054 | 0.059 |
| ( g cm^-1) | Std. Dev. | 0.004 | 0.003 |
| | Tukey Grouping | A | A |
| Percent Moisture | Mean | 89.7 | 87.4 |
| ( % ) | Std. Dev. | 0.64 | 0.31 |
| | Tukey Grouping | A | B |
| Nitrate - T0 | Mean | 0.12 | 0.92 |
| ( µM ) | Std. Dev. | 0.15 | 0.23 |
| | Tukey Grouping | A | B |
| Nitrite - T0 | Mean | 0.59 | 0.75 |
| ( µM ) | Std. Dev. | 0.26 | 0.16 |
| | Tukey Grouping | A | A |
| Nitrification - Nitrate | Mean | 0.78 | -0.71 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 1.15 | 6.05 |
| | Tukey Grouping | A | A |
| Nitrification - Nitrite | Mean | 0.91 | -0.62 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.54 | 2.33 |
| | Tukey Grouping | A | A |
| Denitrification | Mean | -1.59 | -4.20 |
| ( µmole m^-2 h^-1 ) | Std. Dev. | 2.96 | 2.19 |
| | Tukey Grouping | A | A |

Measurements with similar Tukey groupings--both 'A'--indicate similar results.
Measurements with differing Tukey groupings--'A' and 'B'--indicate
significant ($p < 0.05$) differences between the groups.

**Elevation Data**

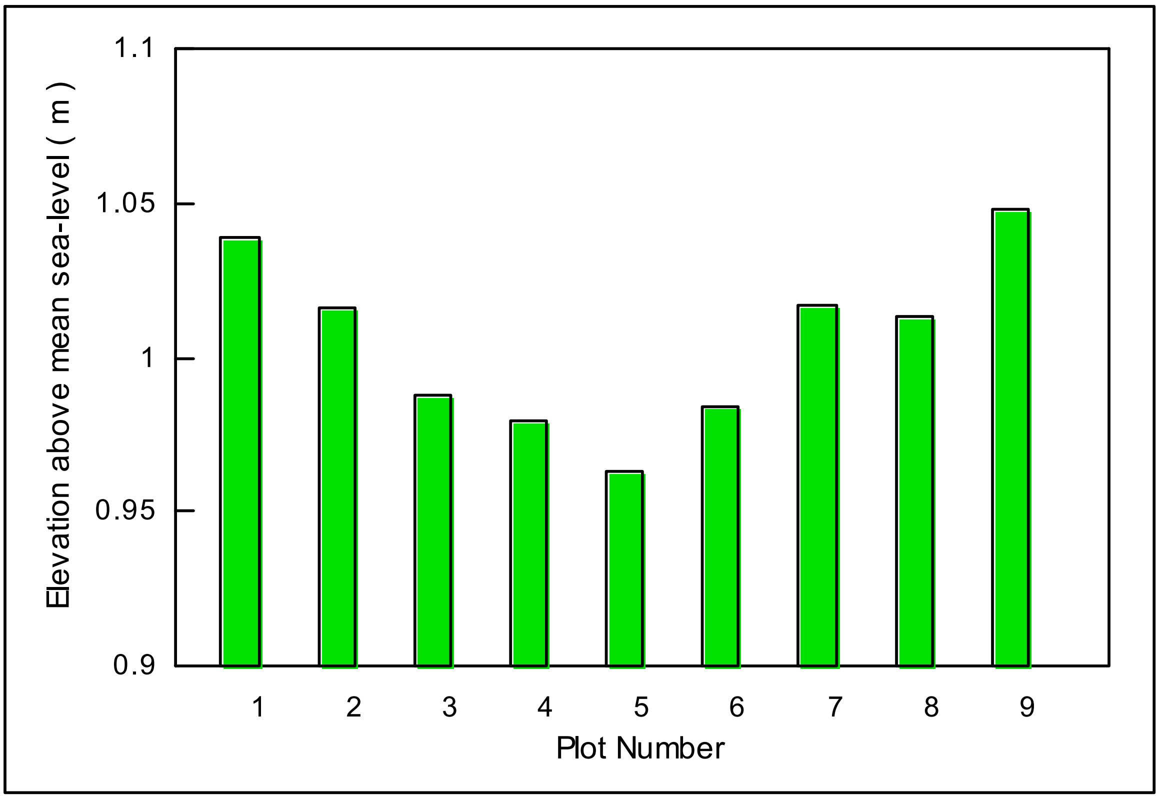
The Brownsville benchmark is located 1.2244 m above mean sea-level. Table 15 lists the elevation of the surveyed points above mean sea-level. Figure 8 illustrates the difference in elevation graphically. Block 2, consisting of plots 4, 5, and 6, lies lower in the marsh than Blocks 1 and 3 (Table 15). Blocks 1 and 3 are lower in elevation towards the direction of Block 2 and reaching higher elevations moving away from Block 2 (Table 15). The elevation in the plots decreases as one moves from the front to the rear—from *S. patens* towards *J. roemerianus*. The float switch lies 165.1 cm below the pump stand that is 2.16 m above mean sea-level. The predicted tide levels were obtained from the VCR world-wide-web browser. According to the predicted tide tables for June, the float switch would have turned the pump on during during all high tide events occuring after noon, but would have turned the pump on only once, on the 1$^{st}$ of June, during the morning hours. During August, all predicted high tides were high enough to turn on the pump. The predicted tides during September rose a minimum of 0.53 m above mean sea-level. September's predicted tides would have activated the float switch during each high tide event during the week leading up to the sampling period. The predicted high tide events during October would have activated the float switch on each high tide with the exception of the high tides occuring in the late evening during the week of October 20 - October 27. Although the predicted high tide charts indicate that no high tide would rise high enough to cover the experimental site, the marsh surface was under water a number of times. The failure of the predicted tables to estimate these flooding events is due to the lack of the model's ability to include the effect of wind on the predicted tide levels.

Table15: Elevation data for the pump stand, brownsville benchmark, and plots.

| Plot # | Area | Height | Brownsville elevation | Elevation difference | Measured elevation | Section elevation |
|---|---|---|---|---|---|---|
| 9 | Left Half | 1.205 | 1.03 | -0.175 | 1.2244 | 1.049 |
| 9 | Left Rear | 1.210 | 1.03 | -0.18 | 1.2244 | 1.044 |
| 9 | Right Rear | 1.215 | 1.03 | -0.185 | 1.2244 | 1.039 |
| 9 | Right Half | 1.195 | 1.03 | -0.165 | 1.2244 | 1.059 |
| 9 | Jun. avg. | 1.206 | | Average | Plot 9 | 1.048 |
| 8 | Left Half | 1.225 | 1.03 | -0.195 | 1.2244 | 1.029 |
| 8 | Left Rear | 1.250 | 1.03 | -0.22 | 1.2244 | 1.004 |
| 8 | Right Rear | 1.245 | 1.03 | -0.215 | 1.2244 | 1.009 |
| 8 | Right Half | 1.245 | 1.03 | -0.215 | 1.2244 | 1.009 |
| 8 | Jun. avg. | 1.241 | | Average | Plot 8 | 1.013 |
| 7 | Left Half | 1.250 | 1.03 | -0.22 | 1.2244 | 1.004 |
| 7 | Left Rear | 1.220 | 1.03 | -0.19 | 1.2244 | 1.034 |
| 7 | Right Rear | 1.255 | 1.03 | -0.225 | 1.2244 | 0.999 |
| 7 | Right Half | 1.225 | 1.03 | -0.195 | 1.2244 | 1.029 |
| 7 | Jun. avg. | 1.238 | | Average | Plot 7 | 1.017 |
| 6 | Left Half | 1.255 | 1.03 | -0.225 | 1.2244 | 0.999 |
| 6 | Left Rear | 1.305 | 1.03 | -0.275 | 1.2244 | 0.949 |
| 6 | Right Rear | 1.260 | 1.03 | -0.23 | 1.2244 | 0.994 |
| 6 | Right Half | 1.260 | 1.03 | -0.23 | 1.2244 | 0.994 |
| 6 | Jun. avg. | 1.270 | | Average | Plot 6 | 0.984 |
| 5 | Left Half | 1.290 | 1.03 | -0.26 | 1.2244 | 0.964 |
| 5 | Left Rear | 1.295 | 1.03 | -0.265 | 1.2244 | 0.959 |
| 5 | Right Rear | 1.285 | 1.03 | -0.255 | 1.2244 | 0.969 |
| 5 | Right Half | 1.295 | 1.03 | -0.265 | 1.2244 | 0.959 |
| 5 | Jun. avg. | 1.291 | | Average | Plot 5 | 0.963 |
| 4 | Left Half | 1.250 | 1.03 | -0.22 | 1.2244 | 1.004 |
| 4 | Left Rear | 1.295 | 1.03 | -0.265 | 1.2244 | 0.959 |
| 4 | Right Rear | 1.290 | 1.03 | -0.26 | 1.2244 | 0.964 |
| 4 | Right Half | 1.265 | 1.03 | -0.235 | 1.2244 | 0.989 |
| 4 | Jun. avg. | 1.275 | | Average | Plot 4 | 0.979 |
| 3 | Left Half | 1.260 | 1.03 | -0.23 | 1.2244 | 0.994 |
| 3 | Left Rear | 1.275 | 1.03 | -0.245 | 1.2244 | 0.979 |
| 3 | Right Rear | 1.275 | 1.03 | -0.245 | 1.2244 | 0.979 |
| 3 | Right Half | 1.255 | 1.03 | -0.225 | 1.2244 | 0.999 |
| 3 | Jun. avg. | 1.266 | | Average | Plot 3 | 0.988 |
| 2 | Left Half | 1.205 | 1.03 | -0.175 | 1.2244 | 1.049 |
| 2 | Left Rear | 1.235 | 1.03 | -0.205 | 1.2244 | 1.019 |
| 2 | Right Rear | 1.260 | 1.03 | -0.23 | 1.2244 | 0.994 |
| 2 | Right Half | 1.255 | 1.03 | -0.225 | 1.2244 | 0.999 |
| 2 | Jun. avg. | 1.239 | | Average | Plot 2 | 1.016 |
| 1 | Left Half | 1.210 | 1.03 | -0.18 | 1.2244 | 1.044 |
| 1 | Left Rear | 1.190 | 1.03 | -0.16 | 1.2244 | 1.064 |
| 1 | Right Rear | 1.250 | 1.03 | -0.22 | 1.2244 | 1.004 |
| 1 | Right Half | 1.210 | 1.03 | -0.18 | 1.2244 | 1.044 |
| 1 | Jun. avg. | 1.215 | | Average | Plot 1 | 1.039 |
| Pump Stand | | 0.095 | 1.03 | 0.935 | 1.2244 | 2.1594 |
| Rusty Benchmark | | 1.030 on front and b | 1.03 | 0 | 1.2244 | 1.2244 |

Pump switch located 165.1 cm below pump stand. Therefore, the pump switch was activated when water rose 0.5084 m above mean sea-level.

Figure 8: The elevation of the plots in relation to mean sea-level.



# Discussion

The general linear model (GLM) analyses were used to assess the effects of the main treatments of Block, Flood, and Vegetation on the redox potential, bulk density, percent moisture of the soil, $NO_3^-$ concentrations, $NO_2^-$ concentrations, and nitrification and denitrification rates. The main treatments and the interaction of Flood*Veg will be discussed as to how they influence the above variables in relation to the proposed hypotheses. In order to determine whether or not the experimental treatments affected rates of nitrification and denitrification it is necessary to understand how these treatments influence the environmental factors of redox potential, bulk density, percent moisture, and $NO_3$ and $NO_2^-$ concentrations.

**Rates of Nitrification and Denitrification**

Measurements of nitrification and denitrification rates made in several studies are shown in Table 16. As observed, the rates estimated in my experiment fall within the range of the above values for both processes (Table 16). Different units are used by different authors. Therefore, it is difficult to make comparisons among all studies. Howard-Williams and Downes (1993) indicated that nitrification rates ranged from 0.01 to 0.03 µM N $g^{-1}$ $d^{-1}$ in salt marsh environments. Thompson et al. (1995) found nitrification rates of 25.0 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$ (25 µmol N $m^{-2}$ $h^{-1}$) (units in parenthesis given by authors) in sediment cores taken from the top 2 cm of natural salt marsh surfaces.

Table 16: A comparison of published nitrification and denitrificaiton

| Study Authors | Date | Nitrification Rates | Denitrification Rates |
|---|---|---|---|
| Howard-Willimas & Downes | 1993 | 0.01 - 0.03 µM $m^{-2}$ $h^{-1}$ | N/A |
| Thompson et al. | 1995 | 25 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$ | 5 µmol $N_2O$ m-2 h-1 |
| Kaplan et al. | 1979 | N/A | 29 µmol $N_2O$ $m^{-2}$ $h^{-1}$ |
| Koch et al. | 1992 | N/A | 2.5 - 59.0 µmol $N_2O$ $m^{-2}$ $h^{-1}$ |
| Reddy et al. | 1989 | N/A | 5.15 µmol $N_2O$ $m^{-2}$ $h^{-1}$ |

Kaplan et al. (1979) found that denitrification rates averaged 29.41 µmol $N_2O$ $m^{-2}$ $h^{-1}$(1 mg N $m^{-2}$ $h^{-1}$) in salt marsh environments. Koch et al. (1992) found in situ denitrification rates in fringing marshes to range from 2.51 to 59.0 µmol $N_2O$ $m^{-2}$ $h^{-1}$(2.51 to 59.0 µmol $N_2$ $m^{-2}$ $h^{-1}$), whereas marsh cores taken from salt marshes had rates as high as 114.87 µmol $N_2O$ $m^{-2}$ $h^{-1}$ (114.87 µmol $N_2$ $m^{-2}$ $h^{-1}$). Reddy et al. (1989) indicated that the maximal potentiol $N_2$ efflux was 5.15 µmol $N_2O$ $m^{-2}$ $h^{-1}$ (42 g N $ha^{-1}$ $d^{-1}$) in a marsh dominated by soft rush. Seitzinger (1988) found that rates ranged from 25 to 125 µmol $N_2O$ $m^{-2}$ $h^{-1}$ (50 to 250 µmol N $m^{-2}$ $h^{-1}$) in coastal marine sediments. Thompson et al. (1995) found denitrification rates of 5 µmol $N_2O$ $m^{-2}$ $h^{-1}$ (10 µmol N $m^{-2}$ $h^{-1}$) in sediment cores taken from the top 2 cm of salt marsh soils.

**Possible Problems**

Errors associated with Eh values obtained to describe the redox potentials given relate to the ability of the probe to measure the redox potential in the oxidized rhizosphere or thin oxidized layer at the soil surface. The redox measurements were taken in the top 0.5 cm of the soil to try and capture the oxidized layer at the soil surface, but the probe could have missed the oxidized areas and not indicated possible areas where nitrification could occur. If roots were within the top 1 cm of the soil, the oxidized root zones were not extensive enough to create an Eh above 200 mV. Also, the measurements of redox potential would have missed the oxidized rhizosphere if they were lower in the soil profile.

I assume accurate rates were obtained for nitrification and denitrification using the acetylene block technique. As described in the Introduction, questions regarding the accuracy of denitrification rates obtained using the acetylene block technique have been raised (Seitzinger et al., 1993). Ryden and Rolston (1983) and Seitzinger et al. (1993) suggest that rates obtained using acetylene would underestimate denitrification rates if

$NO_3^-$ concentrations were below 5 to 10 µM. Concentrations of $NO_3^-$ below 10 µM were routinely measured during all sampling dates. Also, the use of acetylene blockage to measure denitrification will result in underestimating denitrification rates if nitrification provides $NO_3^-$ for denitrification (Seitzinger, 1988). A coupling of nitrification and denitrification has been suggested to occur at Brownsville (Anderson, personal communication). Seitzinger (1988) found that nitrification in marsh soil was the major source of $NO_3^-$ for denitrification. Results of my experiments support the theory that nitrification occurred in the oxidized rhizosphere and indicate a strong coupling of nitrification and denitrification. Although the rates of nitrification and denitrification were very similar, no correlation was observed (Table 17 A-D).

Problems associated with measuring nitrification could begin with possible laboratory errors in measuring $NO_3^-$ concentrations with the cadmium reduction method. Specifically, the cadmium reduction method could have failed to measure the full concentration of $NO_3^-$ by over-reducing the $NO_3^-$ to ammonium, or the reduction could be incomplete (Daniels, personal communication). The cadmium reduction method was tested for percent efficiency using spiked standards and gave accurate and consistent results. Also, the 90 min and 1 h shaking trials measured the same levels of $NO_3^-$ and errors could not be attributed to changing the shaking time. Another possible source of error was the method of obtaining cores. Coring into marsh soil could allow oxygen to reach previously anoxic sites in the sediment. Although the error associated with the coring would be constant between samples, it could overestimate nitrification and possibly denitrification if nitrification and denitrification were coupled. Errors in the nitrification rates could also result from estimating nitrification rates from $NO_3^-$ data and ignoring $NO_3^-$ lost by denitrification since similar $NO_3^-$ concentrations were found in the presence of or absence of aceytlene (Anderson, personal communication).

Table 17: The Pearson Correlation Coefficients produced by SAS to determine if nitrification and denitrification were correlated. The first number indicates to what degree the two processes are correlated. The second number indicates the level of significance, and the last number indicates the number of samples used to obtain the correlation.

A. $NO_3^-$-nitrification and denitrification correlation for August.

| | $NO_3^-$-Nitrification | Denitrification |
|---|---|---|
| $NO_3^-$-Nitrification | 1.0000<br>0.0000<br>52 | 0.2196<br>0.1177<br>52 |
| Denitrification | 0.2196<br>0.1177<br>52 | 1.0000<br>0.0000<br>54 |

B. $NO_2^-$-nitrification and denitrification correlation for August.

| | $NO_3^-$-Nitrification | Denitrification |
|---|---|---|
| $NO_3^-$-Nitrification | 1.0000<br>0.0000<br>54 | -0.0262<br>0.8508<br>54 |
| Denitrification | -0.0262<br>0.8508<br>54 | 1.0000<br>0.0000<br>54 |

C. $NO_3^-$-nitrification and denitrification correlation for September.

| | $NO_3^-$-Nitrification | Denitrification |
|---|---|---|
| $NO_3^-$-Nitrification | 1.0000<br>0.0000<br>54 | 0.1278<br>0.3571<br>54 |
| Denitrification | 0.1278<br>0.3571<br>54 | 1.0000<br>0.0000<br>54 |

D. $NO_2^-$-nitrification and denitrification correlation for September.

| | $NO_3^-$-Nitrification | Denitrification |
|---|---|---|
| $NO_3^-$-Nitrification | 1.0000<br>0.0000<br>54 | -0.0019<br>0.9890<br>54 |
| Denitrification | -0.0019<br>0.9890<br>54 | 1.0000<br>0.0000<br>54 |

In the field, a possible problem arises from the dependability of constant delivery of water throughout the term of the experiment. The amount of water pumped from April until July was 27,265 gallons or 103.2 $m^3$ of water—an average of 9,088 gallons or 34.4 $m^3$ of water per month. As an example, a total of 2,681 gallons (10.15 $m^3$ of water) were pumped during the week of April 21, 1994, but these values are high due to the presence of spring tides. Not only did the pump have to be replaced during late June/ early July, but the batteries were not charged sufficiently to power the pump each high tide in September. The pump gauge read 63,265 on July 7, 1994, and the last reading was 52,748 on September 23, 1994, but no water had been pumped since September 16, 1994. These readings indicate that 10,517 gallons (39,964.6 L) or approximately 40 $m^3$ of water were pumped after July 7, 1994. Using the data begining on July 7, 1994, enough water was pumped during each high tide to add 7.9 mm of water to the marsh surface in each of the flooded plots. According to Hemond et al. (1984), a small amount of water infiltration could raise the water table observed in water-level wells five times higher than the amount of water infiltrating the marsh soil. The reading of the water-level recorder is a measure of an average of the pore pressure over the height of the well where water exchange occurs with the surrounding sediments.

The blocks were used for replication purposes in the statistical tests. However, all measured variables exhibited large among-block variations. These among-block variations could be due to spatial variability or to differences in elevation between the different plots. Differences in measurements among blocks could account for measurements and rates not being statistically affected by the treatments in each block. However, similar significant results were obtained when the data were analyzed by Block. The statistically similar results obtained by analyzing the data by Block indicate that the results obtained reflect real differences in the processes and not the among-block variation. Also, the small differences in elevation between the plots present at the experimental site did not affect the significance of the results.

**Short-Term Effects**

October's experiment was conducted to discover if results obtained during June, August, and September could have been influenced by short-term events such as flooding in the field or changes in moisture during transit. As described earlier, flooding can prevent oxygen from diffusing to the thin oxidized layer at the water-soil interface, increase nutrient inputs, and dilute salinities. October's results indicate that only the percent moisture was affected by drying, and that differences in nitrification and denitrification rates were not significantly changed by the soil's percent moisture or by an approximate 12 h drying period. However, nitrification and denitrification rates were low throughout all treatments—probably due to the lack of the presence of wrack or to the low Eh values that limit nitrification and nitrate production. Different results might have been obtained if wrack had been present or if higher rates had been observed.

The thin oxidized layer at the soil-water interface is a location where some nitrification occurs (Mitsch & Gosselink, 1993), but less oxygen is available there during short-lived flooding events. Patrick and DeLaune (1972) indicated that the highest redox potentials were found in the top 1 cm of the soil. Although activity in microsites is possible, the integrated redox potentials at the oxidized layer of the soil-water interface appeared to be low enough to preclude oxygen and possibly nitrification. The other site of nitrification activity in flooded soils, the oxidized rhizosphere, would not be as directly affected by the flooding since the roots are already in saturated soil conditions (Reddy et al., 1989). The oxidized rhizosphere could be the location where most nitrification occurred. In conclusion, short-lived changes in soil moisture content in marsh soil do not appear to cause significant changes in nitrification or denitrification rates when the rates are very low (Table 14).

**Long-Term Effects**

Tables 2 - 13 review the significant effects caused by the main treatments as well as the interactions of the main treatments during June, August, and September. Table 18 shows the precipitation, wind speed, wind direction, solar radiation, photosynthesis radiation, and minimum, maximum, and average temperatures for the few days before and the time during the sampling for June, August, and September, respectively. The long-term effects include the effects of alternate flooding conditions and wrack deposition on the nitrogen cycle.

**Flooding**

**FH1**: **Increased flooding will decrease the available $O_2$ and thereby lower the Eh.**

Flooding did not affect the redox potentials in the top 1 cm of the marsh soil. During August, the **BC** plots had lower Eh values than the **C** and **F** plots which had similar values (Table 9). The **BC** plots could hold water due to the surrounding border, where a layer of overlying water may prevent oxygen from entering the soil at a rate to offset consumption. Similarly, the border around the **BC** plots would reduce mixing of oxygen-rich water associated with a high tide event. The reduction of mixing could prevent oxygen from entering the overlying water and reaching the soil. This would keep redox potentials from rising. Similarly, the **C** and **F** plots could have higher redox potentials due to more oxygen being able to reach the soil. Oxygen could reach the soil in the **F** plots by being in the creek water during pumping. Likewise, the **C** plots could retain less water due to the lack of a border. However, the results of the percent moisture measurements do not support these two hypotheses.

The redox measurements are an average of the electron potential across a large area. Small oxidized areas such as areas near the soil surface and the oxidized rhizo-

| Month & Day | | Precipitation (mm) | Averate Temperature (degrees Celcius) | Wind Speed (m / s) | Wind Direction (degrees) | Solar Radiation (KJ / sq. m) | Photosynthetic Radiation (uE / sq. m) |
|---|---|---|---|---|---|---|---|
| June | 1 | 25.7 | 24 | 3.2 | 254 | 25314 | 45741 |
| | 2 | 0.00 | 19.4 | 1.84 | 340 | 27756 | 49374 |
| | 3 | 0 | 17 | 1.27 | 76 | 29735 | 52105 |
| | 4 | 0 | 19.7 | 0.83 | 307 | 28669 | 50021 |
| Aug. | 15 | 24.4 | 20.6 | 0.07 | 347 | 7,503* *possible error | 78254 |
| | 16 | 0 | 19.7 | 0.02 | 164 | 3,973* *possible error | 49342 |
| | 26 | 0 | 25.1 | 1.34 | 231 | 13731 | 23448 |
| Sept. | 22 | 65.1 | 19.8 | 4.69 | 82 | 3424 | 6973 |
| | 23 | 0 | 18.8 | 2.92 | 275 | 15961 | 28252 |
| | 24 | 0 | 19.2 | 0.29 | 93 | 13360 | 24580 |
| | 25 | 0 | 22.1 | 0.36 | 133 | 11589 | 21312 |
| | 26 | 0 | 23.4 | 0.34 | 129 | 13520 | 24745 |

sphere are included in the average, but very low redox potentials elsewehere have the ability of keeping the measured Eh values low. Therefore, the oxidized areas that have higher Eh values might not be observed in my measurements.

The results of the percent moistures were also unexpected. The values obtained in the **F** plots were statistically similar to those in the **C** and **BC** plots, but the **C** plots had significantly higher percent moistures than the **BC** plots in August. No difference was observed in the percent moistures measured among the flooding conditions in September. The flooding treatments failed to affect percent moistures of the soil in the predicted manner and could indicate that soils do not dry out that much in the marsh. The sampling dates coincided with spring tides, and the higher tides could have kept the marsh wetter. Although no high tide was predicted to rise above 0.90 m, numerous high tide events rose 0.75 m above mean sea-level. These high tides, acting in concert with wind events, could cause flooding events that would cover the marsh surface with several to tens of cm of water. The high tides associated with spring tides could keep the marsh surface wetter than it would have been during neap tides. Also, ground water may keep the organic soils moist. Hemond et al. (1984) found that water lost by evapotranspiration was replaced by groundwater from adjacent soil. Groundwater may have flowed horizontaly towards the tidal creek from the upland sites, and the percent moistures of the soil indicated that the soils were almost saturated or were saturated.

The main factor that would account for no change being observed is that the system is well poised to absorb changes in the flooding regime. The failure to pump enough water on the plots to affect the redox potentials might also be a factor, but does not seem likely to be a factor since an average of 7.9 mm of water were added to the **F** plots during each high tide event. Although the pumping would only affect the **F** plots, the **C** plots would be expected to have higher redox potentials than the **F** or **BC** plots.

The **F** and **C** plots would then be expected to have higher redox potentials than the **BC** plots if the pumping process added $O_2$-rich water to the plots.

**FH2: Pumping tidal creek water onto the flooded plots will increase concentrations of $NO_3^-$.**

The $NO_3^-$ concentrations were significantly higher in the **C** plots than in the **F** plots during June and August. The concentrations in the **BC** plots were statistically similar to the concentrations measured in both the **F** and **C** plots during June and August. However, no significant differences among flooding conditions were noted in $NO_3^-$ concentrations during September.

These observed differences were not explained by nitrification rates in the flooding treatments since September's nitrification rates were between the highest rates, observed in August, and the lowest rates, observed in June. Although no measurements for denitrification were taken in June, denitrification did not seem to account for the differences in $NO_3^-$ concentrations during August and September since denitrification rates in flooded sections were higher in September than in August (Tables 10 & 6). The differences among treatments in June and August could indicate that flooding reduced the $NO_3^-$ concentrations in the plots. Since no difference in $NO_3^-$ concentrations were detected during September, the hypothesis could not be supported. The measurement of percent moisture during August exhibited similar patterns as the $NO_3^-$ concentrations—namely highest in the **C** plots and lowest in the **F** plots. In September, no significant differences were observed in the percent moistures or in the concentration of $NO_3^-$. These similarities seem to indicate that the concentration of $NO_3^-$ increases as the percent moisture increases.

The $NO_3^-$ concentrations indicated that more $NO_3^-$ was available for denitrification in **C** and **BC** plots than in the **F** plots (Tables 6 & 10). The $NO_2^-$ concentrations mirrored the trends in $NO_3^-$ concentrations except in June where the **F** plots had the highest $NO_2^-$ concentrations and the **B** plots had the lowest concentrations. The results indicated that flooding did not consistently increase the standing stocks of $NO_3^-$ or $NO_2$.

**FH3: If FH1, flooding will decrease nitrification rates**.

The flooding conditions did not significantly affect nitrification rates during June, August, or September. As described earlier, the concentrations of $NO_3^-$ and $NO_2^-$ do not indicate that nitrification was affected by the flooding treatment. The lack of any effect could reflect the marsh soil already having been saturated. Even though the percent moistures varied depending on the treatment during August, the difference between the highest and lowest percent moistures was only 2 percent and not likely to cause significant changes in the measured rates. Nitrification in vegetated areas probably occurred in thin oxidized areas unaffected by such a change (Reddy et al., 1989). Since flooding also failed to alter the reducing conditions, it might also have failed to alter nitrification rates.

More drastic changes in flooding regimes, such as those found along tidal creeks with increased drainage might be needed for flooding conditions to alter the rates of nitrification and denitrification. Areas along tidal creeks were flooded during each high tide, and the marsh soil along the creek bank remained submerged longer than the soil in the **F** plots. Also, soil near creek banks drains quickly, and conditions between high and low tide are markedly different. These conditions include the height of the overlying water column, the redox potential, and the percent moisture (Blum, 1993).

The **F** plots received flooding, but the water pumped to the plots was added from above similar to overland flow. The added water was pumped through PVC pipes, and nutrient exchanges between the flooding water and the marsh surface did not occur as they would under natural flooding conditions.

The flooding treatments failed to affect nitrification rates. This failure indicates that flooding failed to inhibit nitrification in the oxidized soil-water interface or in the oxidized rhizosphere. The oxidized soil-water interface is located in the top few millimeters of the soil surface (Mitsch & Gosselink, 1993), and the methods used in my experiment measured changes in the top 3 cm of the marsh surface. My method of measuring nitrification is the top 2.5 to 3 cm of soil, and both oxidized locations were located within the soil sampled. The oxidized locations seem to remain oxidized, and nitrification occurs in those areas even if flooding conditions change as they did during the experiment. The microbial community responsible for nitrification appears capable of dealing with changes in the flooding regimes. This ability to deal with the added stress is explained by the inability of the flooding to alter the oxidized locations where nitrification occurs in salt marsh sediments. The flooding might affect the processes, but processes might only be affected during the period of flooding.

**FH4: a. If $NO_3^-$ from the tidal water limits denitrification and FH2 occurs, the first two hypotheses lead to increases in denitrification rates.**

**b. If $NO_3^-$ from nitrification limits denitrification and FH3 occurs, flooding will decrease the rate of denitrification.**

**c. If $NO_3^-$ does not limit the rate of denitrification, flooding and nitrification will not affect denitrification rates**.

As with nitrification rates, the flooding conditions did not significantly affect denitrification rates during August or September. Likewise, $NO_3^-$ concentrations did not seem to predict denitrification rates. Denitrification rates during August were higher in the **BC** plots and lowest in the **F** plots (Table 6), but the rates were not significantly different. However, denitrification rates in September were statistically similar among the flooding treatments, but rates were highest in the **C** plot and lowest in the **BC** plots (Table 10). $NO_3^-$ concentrations were higher in the **C** plots and lowest in the **F** plots during August, but the differences did not appear to indicate $NO_3^-$ concentrations affected denitrification rates (Table 6). The only similarity in $NO_3^-$ concentrations and denitrification rates were the low rates and low concentrations in the **F** plots. The low concentrations in the **F** plots could have been attributed to higher denitrification in the **F** plots, but lower rates were measured in those plots (Tables 6 & 10).

Another explanation for failure of flooding to affect denitrification rates could be that nitrification was limited by the flooding or that nitrification was boosted in the **BC** and **C** plots, but nitrification rates were similar regardless of flooding conditions (Tables 2, 6, & 10). This could support the hypothesis that $NO_3^-$ from nitrification could be the source of $NO_3^-$ used by the denitrifyinng bacteria since since flooding did not affect either nitrification or denitrification rates.

The lack of any effect on denitrification rates could also be due to the marsh soil already being saturated. Since flooding failed to alter the reduced conditions, the flooding might have failed to alter denitrification rates.

I cannot reject a hypothesis that denitrification is limited by $NO_3^-$ provided by nitrification. It is difficult to correlate rates of nitrification and denitrification with standing stocks of $NO_3^-$ since $NO_3^-$ pools might be turning over very rapidly. However, Reddy et al. (1989) indicated nitrification was coupled to denitrificaition in salt marsh environments. Koch et al. (1992) and Seitzinger (1988) indicated that denitrification is limited by $NO_3^-$ availability. Since nitrification is a source of $NO_3^-$, nitrification if occuring in oxidized locations within anaerobic soils is generally coupled to denitrification.

**Wrack Deposition**

**WH1: Wrack will lower the Eh of the marsh soil.**

Wrack-covered areas have statistically similar redox potentials in the top 1 cm of soil as vegetated sections (Tables 6 & 10). Since the range in the redox potentials was lower than 250 mV, reduced conditions existed and oxygen was only available in the thin oxidized soil-water interface and in the oxidized rhizosphere (Reddy et al., 1989). Blum (1993) found low redox potentials in vegetated areas within 10 m of the tidal creek. Blum (1993) measured redox potentials over depth—starting at 1 cm and continuing down to a depth of about 32 cm—and found that all measured electrode potentials were below 130 mV, and the highest reading (130 mV) was measured at a depth of 1 cm. As mentioned earlier, the redox measurements are an average of the electron potential across a large area. Small oxidized areas such as the oxidized soil-water interface and the oxidized rhizosphere are included in the average, but very low redox potentials elsewehere have the potential to keep the measured Eh values low. Therefore, the oxidized areas that have higher Eh values might not be observed in my measurements.

**WH2: Wrack will increase the percent moisture in the soil.**

Wrack did not seem consistently to influence the percent moisture of the soil. Samples from wrack-covered sections had significantly higher ($p < 0.05$) percent moisture measurements than those from vegetated areas (Table 6) in August. As discussed, percent moistures were lower in August than in September by approximately 2 percent. This increased percent moisture might be due to the 6.5 cm of rainfall on September 22, 1994. No significant difference was noted in percent moistures between vegetated and wrack-covered sections in September (Table 10). The lack of a difference in September could have been due to the higher percent moistures in September than in August (Porter et al., 1995). It might be possible that wrack could have provided shelter from sunlight and reduced evapotranspiration. In addition, the wind speed in September was over 1.2 m $s^{-1}$ faster on average than in August, but the wind did not seem to affect the percent moisture of the soil since percent moistures measured in September were higher than those measured in August. (Porter et al., 1995).

**WH3: Vegetated areas will have higher nitrification rates than wrack-covered areas if wrack lowers the $O_2$ in the soil.**

Vegetated areas had similar nitrification rates as wrack-covered areas. This result tends to repute the hypothesis that nitrification was occurring solely in the oxidized rhizosphere through ROL. As pointed out in WH1, the wrack did not have a significant effect on Eh values. The fact that vegetated areas did not have higher nitrification rates could be explained if the thin oxidized layer at the soil-water interface was the location of nitrification. Likewise, ROL might have occurred in some areas in the wrack treatment since a few *J. roemerianus* plants survived and grew up through the wrack. Also, oxygen diffusion may have occurred through the dead stems of the *J. roemerianus*. *J. effusus* has the ability to exude oxygen through its roots (Reddy et al., 1989), and *J. roemerianus* is assumed to have the same ability. Although not measured, the limited number of surviving plants might be able to account for the lack of difference in nitrification rates between vegetated and wrack-covered sections.

Nitrification seems to occur in both oxidized locations and might be increased when wrack is present as they were in September. Since wetland plants have been shown to be limited by $NH_4^+$ availability, the $NH_4^+$ not used by the dead vegetation could be available for the nitrifying bacteria. In fact, wrack-covered sections had significantly higher $NH_4^+$ concentrations than the vegetated areas.

Although no significant difference in nitrification rates was observed in August, the failure could be due to the estimate of nitrification being obtained using $NO_3^-$ concentration data especially since this method ignores concurrent denitrification. However, the vegetated areas had twice the nitrification rate as the wrack-covered areas. June's $NO_3^-$-nitrification data supports a hypothesis that vegetated areas have higher nitrification rates than wrack-covered areas. As described earlier, this result could occur since the nitrification measurements do not account for the $NO_3^-$ used by the denitrification pathway and are suggested to underestimates the $NO_3^-$ produced in wrack-covered areas**.**

**WH4: The presence of wrack will increase denitrification rates because of WH1.**

Denitrification rates were higher in wrack-covered sections than in vegetated sections during both months. Since $NO_3^-$ concentrations were not higher in wrack-covered areas in August, the increases in standing stocks of $NO_3^-$ were insufficient to explain the higher denitrification rates observed in wrack-covered areas. As mentioned, changes in $NO_3^-$ concentrations are not easily used to explain changes in denitrification rates since the $NO_3^-$ pool could be turning over rapidly.

Denitrification has been postulated to occur in microsites where it can exist even when flooding conditions change (Christensen et al., 1990). Christensen et al. (1990) indicated that denitrification activity was driven by anaerobic microorganisms using organic matter as an electron donor. Additionally, Christensen et al. (1990) postulated that the absence of these microsites would limit denitrification more than the limitation caused by $NO_3^-$ concentrations. Christian et al. (1978) demonstrated that the microbial community was resistant to ecosystem perturbation, and denitrification rates might not have been affected by small changes in the redox potential since the redox potential was always low enough to reduce $NO_3^-$.

Added particulate organic matter has been shown to increase denitrification rates (Seitzinger, 1988), and the decomposition of wrack could have added organic matter to the marsh soil. In addition to the decomposing wrack, the dying underlying vegetation would decompose, and the dying plants could provide organic matter for the denitrifying bacteria. This addition of organic matter would provide carbon and nitrogen for denitrifiers living within the microsites allowing for greater rates of denitrification

(Christensen et al., 1990). Weier et al. (1993) found that denitrification rates increased as the amount of organic carbon increased. Sherr and Payne (1978) found that removing the roots of *S. alterniflora* plants decreased the soil denitrification potential. Specifically, the results of their experiment indcate that *S. alterniflora* roots exude organic matter into the soil and that the added organic matter increases the potential for denitrification (Sherr & Payne, 1978) Therefore, denitrification could be increased by the addition of wrack since marsh anaerobes have been hypothesized to be nutrient limited by the slow transformation of organic matter in the soil (Christian et al., 1978).

**Interaction**

**IH1: Flooded wrack-covered sections will have higher denitrification rates than sections just flooded or wrack-covered.**

As discussed, the wrack-covered sections had higher denitrification rates than vegetated sections regardless of flooding condition. Actually, flooded wrack-covered sections had lower yet statistically similar denitrification rates than wrack-covered sections in the border control and control plots. In fact, the flooded wrack-covered sections in August and September had the lowest rates of denitrification of any wrack-covered sections regardless of flooding treatment (Tables 9 & 13). The **BC** plots covered with wrack had the highest denitrification rates in August, whereas the wrack-covered **C** plots had the highest rates in September.

As seen before, the wrack exerts a powerful influence on denitrification rates. Weier et al. (1993) showed that increases in percent moisture and added organic matter increase denitrification rates. However, the interaction of flooding and vegetation in this study failed to show any added influence on the process. The failure to notice the interaction could be caused if flooding failed to affect denitrification. If, as postulated, the microbial community is resiliant to changes in flooding regimes, the interaction would not be noticed. In addition, wrack-covered areas had higher ($p < 0.05$) percent moistures in August, but no difference was observed in September. Perhaps the combination of reduced conditions and differences in percent moisture could account for the Flood*Veg interactions from being significant.

**Summary**

Referring back, Figure 4 illustrates the postulated effects wrack addition has on the processes of nitrification and denitrification. The effect each of the conditions has on the processes, indicated by the “+” or “-” signs, appears correct. However, the intensity of the effect on the processes differs since flooding fails to consistantly affect the processes, whereas the vegetative cover consistantly affects the processes of nitrification and denitrification. Nitrification is suggested to be relatively unaffected by flooding events in the locations where the process occurs—namely the oxidized rhizosphere and oxidized soil-water interface. However, nitrification rates are suggested to be higher in wrack-covered areas since denitrification is also higher in those areas, and denitrification would remove $NO_3^-$ produced through nitrification. Denitrification was only affected by the disturbance of wrack deposition.

In their paper on multiple states in the sea-level induced transition from terrestrial forest to estuary, Brinson & Christian (1995) illustrate that changes in marsh vegetation occur not after stress producing events like flooding events but after disturbance events like wrack deposition. In this study, flooding did not significantly affect nitrification or denitrification rates. As discussed, either the pumping of water was not able to affect these processes or, more likely, the processes occur in areas where they are protected from perturbations in flooding and where the sediment remains saturated. Even if the spring tides obscured any effects of flooding, the results still indicate a lack of a long-term effect. Nitrification appeared to occur both in the oxidized thin layer at the soil-water interface and in the oxidized rhizosphere. Denitrification is suggested to occur in microsites where organic matter is actively being metabolized.

The presence of wrack only increased nitrification rates during September. However, the method used to measure nitrification failed to incorporate the $NO_3^-$ removed through denitrification. The methods that were used to measure nitrification are suggested to have underestimated the rate of nitrification occurring in wrack-covered areas since wrack-covered areas had higher denitrification rates. Wrack increased denitrification rates during August and September. If nitrification occured in both oxidized locations, a perturbation affecting one location might not influence the rates in the other. The wrack could increase denitrification rates by providing more labile carbon required for denitrification through nitrification.

Although flooding frequency failed to affect nitrification and denitrification in this experiment, wrack deposition affected the process of denitrification and sometimes nitrification. Specifically, wrack deposition significantly increased denitrification rates during all months sampled. The effect produced on the two processes could be explained if the community of bacteria that nitrify and denitrify are well suited to deal with changes in flooding conditions. The bacterial community would be expected to be resilient to flooding regimes due to the changes in flooding conditions found in tidal salt marshes. Also, failure of a treatment to affect the rates could be explained if the soil microhabitat structure was not altered greatly by the treatments. The soil is very peaty (as indicated by very low bulk densities), and this condition may maintain aerobic and/or anaerobic interfaces in the face of changes in flooding frequency as conducted in this study. However, disturbance events, like wrack deposition, alter the conditions of the marsh and affect the processes of nitrification and denitrification.

# Appendix A

In order to correct the $N_2O$ concentration measured in the core headspace for that dissolved in sediment pore water, the data was corrected using an equation:

$$\text{Total N2O} = [C_{N2O}(V_g+((V_l)(O_c)))] \qquad [1]$$

In equation 1, $C_{N2O}$ equals the concentration of $N_2O$ (ppm) from the core sample; $V_g$ equals the total volume (ml) of gas in the core tube; $V_l$ equals the total volume (ml) of liquid in the core tube; and $O_c$ represents the Oswald Coefficient.

The Bunsen solubility coefficient is the volume of gas at standard temperature and pressure (STP) absorbed per unit volume of solution when the total pressure and the fugacity are both equal to 1 ATM (Weiss and Price, 1980). It was derived from 3 and 4:

$$K_o = ß/V^r \qquad [3]$$

$$ß = (K_o)(V^r) \qquad [4]$$

$K_o$ is the equilibrium constant defined as the concentration of the solute in moles per liter of solution, and $V^r$ is the volume of one mole of the pure real gas at standard conditions, STP (Weiss and Price, 1980). The gas constant's units are 1 ATM / ml liquid, and $T_k$ is the temperature measured in Kelvin. ATM represents atmospheric pressure—1 ATM equals 101.325 kPa, 760 Torr, or just over 1 bar (100 kPa) (One Pa equals one newton per square meter).

The Oswald Coefficient equals the Bunsen solubility coefficient, ß, multiplied by the product of the gas constant and the temperature:

$$O_c = (ß)((0.08205601)(T_k)) \qquad [2]$$

The following formulas were obtained from Weiss and Price, 1980. To obtain $V^r$, or $V^r(P,T)$, formula 5 uses the volume of one mole of ideal gas, $V^i(P,T)$, and the second virial coefficient, B(T), to obtain the volume of one mole of real gas (STP). In formulas 5 and 6, which illustrate the computation of $V^i(P,T)$ and B(T), P and T represent pressure

(ATM) and temperature (Kelvin).

$$V^{i}(P,T) = V^{r}(P,T)+B(T) \quad [5]$$

$$B(T) = [-905.95+4.1685(T)-0.0052734(T^{2})] \quad [6]$$

$K_o$ is obtained from:

$$\ln K_o = [C_1+C_2(100/T)+(C_3(\ln(T/100)))]+$$
$$[S(C_4+C_5(T/100)+C_6(T/100)^{2} \quad [7]$$

where $C_{1\text{-}6}$ are the constants listed in Table A1, S represents the salinity of the sample in ppt, and T is the temperature in Kelvin. $K_o$ was derived from formula 7 using formula 8:

$$K_o = e^{\ln Ko} \quad [8]$$

Once all of the values had been determined, the total $N_2O$ was obtained and expressed in nanomoles per meter squared, nmol/$m^2$.

Table A1: Values of the constants used in the calculations to estimate denitrification rates.

| Constant | Value |
|---|---|
| $C_1$ | -62.7062 |
| $C_2$ | 97.3066 |
| $C_3$ | 24.1406 |
| $C_4$ | -0.05842 |
| $C_5$ | 0.033193 |
| $C_6$ | -0.0051313 |

# Appendix B

The following are the data from the experiment. Ammonium, nitrate, nitrite, and nitrous oxide concentration data are included in the following Tables B1 - B4. The tables are presented in chronological order beginning with June (B1) and ending in October (B4). The ammonium, nitrate, and nitrite concentrations are presented in µM and µmol $m^{-2}$ $h^{-1}$. The nitrous oxide data are presented in ppm and µmol $m^{-2}$ $h^{-1}$. The data listed are the raw data that were converted to obtain estimates of nitrification and denitrification.

Table B2: The raw data for June. The table indicates the Block, Flooding condition, Vegetation treatment, Incubation treatment and core number. Flooding treamtnets include flooded (F), border control (BC), and control (C). Vegetation treatments include wrack covered (W) and vegetated areas (J). Incubation treatments include the incubation time (0, 1, or 6 hours) and added liquid--Acetylene (A) or Deionized water (D). The data include ammonium, nitrate, nitrite, and nitrous oxide concentrations.

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate ( µM ) | Nitrite ( µM ) |
|---|---|---|---|---|---|---|
| Block 1 | C | W | 0 hr - A | 1 | no sample | no sample |
| Block 1 | C | W | 0 hr - A | 2 | 2.32 | 1.73 |
| Block 1 | C | W | 0 hr - A | 3 | 2.47 | 1.75 |
| Block 1 | C | W | 1 hr - A | 4 | 0.78 | 0.82 |
| Block 1 | C | W | 1 hr - A | 5 | 2.46 | 1.33 |
| Block 1 | C | W | 1 hr - A | 6 | 3.97 | 1.41 |
| Block 1 | C | W | 1 hr - D | 7 | 0.78 | 0.32 |
| Block 1 | C | W | 1 hr - D | 8 | 0.68 | 0.52 |
| Block 1 | C | W | 1 hr - D | 9 | 2.78 | 0.87 |
| Block 1 | C | W | 6 hr - A | 10 | 1.75 | 0.76 |
| Block 1 | C | W | 6 hr - A | 11 | 1.36 | 0.46 |
| Block 1 | C | W | 6 hr - A | 12 | 0.54 | 1.04 |
| Block 1 | C | W | 6 hr - D | 13 | no sample | no sample |
| Block 1 | C | W | 6 hr - D | 14 | 0.96 | 0.41 |
| Block 1 | C | W | 6 hr - D | 15 | 0.61 | 0.57 |
| Block 1 | C | J | 0 hr - A | 16 | 1.02 | 1.49 |
| Block 1 | C | J | 0 hr - A | 17 | 4.18 | 0.99 |
| Block 1 | C | J | 0 hr - A | 18 | 2.21 | 2.00 |
| Block 1 | C | J | 1 hr - A | 19 | 0.88 | 1.63 |
| Block 1 | C | J | 1 hr - A | 20 | 2.90 | 4.12 |
| Block 1 | C | J | 1 hr - A | 21 | 0.42 | 1.29 |
| Block 1 | C | J | 1 hr - D | 22 | 0.48 | 0.44 |
| Block 1 | C | J | 1 hr - D | 23 | 0.55 | 0.84 |
| Block 1 | C | J | 1 hr - D | 24 | 1.32 | 1.38 |
| Block 1 | C | J | 6 hr - A | 25 | 0.21 | 1.13 |
| Block 1 | C | J | 6 hr - A | 26 | 0.96 | 1.08 |
| Block 1 | C | J | 6 hr - A | 27 | 0.40 | 2.08 |
| Block 1 | C | J | 6 hr - D | 28 | 0.00 | 0.89 |
| Block 1 | C | J | 6 hr - D | 29 | 0.40 | 0.72 |
| Block 1 | C | J | 6 hr - D | 30 | 0.00 | 0.66 |
| Block 1 | F | W | 0 hr - A | 31 | 0.76 | 0.56 |
| Block 1 | F | W | 0 hr - A | 32 | 2.08 | 1.68 |
| Block 1 | F | W | 0 hr - A | 33 | 0.48 | 0.89 |
| Block 1 | F | W | 1 hr - A | 34 | 1.45 | 0.93 |
| Block 1 | F | W | 1 hr - A | 35 | 0.19 | 1.58 |
| Block 1 | F | W | 1 hr - A | 36 | 0.62 | 0.86 |
| Block 1 | F | W | 1 hr - D | 37 | 2.35 | 1.60 |
| Block 1 | F | W | 1 hr - D | 38 | no sample | 0.59 |
| Block 1 | F | W | 1 hr - D | 39 | 0.43 | 1.63 |
| Block 1 | F | W | 6 hr - A | 40 | 0.60 | 1.01 |
| Block 1 | F | W | 6 hr - A | 41 | 0.00 | 1.68 |
| Block 1 | F | W | 6 hr - A | 42 | 2.56 | 0.86 |
| Block 1 | F | W | 6 hr - D | 43 | 1.17 | 0.72 |
| Block 1 | F | W | 6 hr - D | 44 | 0.23 | 0.74 |
| Block 1 | F | W | 6 hr - D | 45 | 0.00 | 1.51 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate uM | Nitrite uM |
|---|---|---|---|---|---|---|
| Block 1 | F | J | 0 hr - A | 46 | 1.03 | 0.76 |
| Block 1 | F | J | 0 hr - A | 47 | 0.91 | 0.64 |
| Block 1 | F | J | 0 hr - A | 48 | 0.12 | 0.92 |
| Block 1 | F | J | 1 hr - A | 49 | 0.31 | 1.48 |
| Block 1 | F | J | 1 hr - A | 50 | 0.70 | 1.14 |
| Block 1 | F | J | 1 hr - A | 51 | no sample | 0.54 |
| Block 1 | F | J | 1 hr - D | 52 | 0.02 | 0.84 |
| Block 1 | F | J | 1 hr - D | 53 | 0.00 | 2.11 |
| Block 1 | F | J | 1 hr - D | 54 | 0.33 | 1.36 |
| Block 1 | F | J | 6 hr - A | 55 | 1.42 | 0.82 |
| Block 1 | F | J | 6 hr - A | 56 | 0.31 | 0.39 |
| Block 1 | F | J | 6 hr - A | 57 | 1.23 | 0.77 |
| Block 1 | F | J | 6 hr - D | 58 | 0.65 | 0.92 |
| Block 1 | F | J | 6 hr - D | 59 | 0.71 | 0.89 |
| Block 1 | F | J | 6 hr - D | 60 | no sample | 1.03 |
| Block 1 | BC | W | 0 hr - A | 61 | 2.31 | 1.16 |
| Block 1 | BC | W | 0 hr - A | 62 | 1.16 | 1.24 |
| Block 1 | BC | W | 0 hr - A | 63 | no sample | 0.67 |
| Block 1 | BC | W | 1 hr - A | 64 | 0.20 | 0.64 |
| Block 1 | BC | W | 1 hr - A | 65 | 2.18 | 1.95 |
| Block 1 | BC | W | 1 hr - A | 66 | no sample | no sample |
| Block 1 | BC | W | 1 hr - D | 67 | 0.51 | 0.81 |
| Block 1 | BC | W | 1 hr - D | 68 | 1.48 | 1.06 |
| Block 1 | BC | W | 1 hr - D | 69 | 0.71 | 0.66 |
| Block 1 | BC | W | 6 hr - A | 70 | 0.48 | 0.81 |
| Block 1 | BC | W | 6 hr - A | 71 | 1.17 | 0.57 |
| Block 1 | BC | W | 6 hr - A | 72 | 1.32 | 0.42 |
| Block 1 | BC | W | 6 hr - D | 73 | 0.85 | 1.03 |
| Block 1 | BC | W | 6 hr - D | 74 | 1.26 | 0.69 |
| Block 1 | BC | W | 6 hr - D | 75 | 0.32 | 0.49 |
| Block 1 | BC | J | 0 hr - A | 76 | 1.42 | 1.28 |
| Block 1 | BC | J | 0 hr - A | 77 | 2.18 | 0.41 |
| Block 1 | BC | J | 0 hr - A | 78 | 0.28 | 0.66 |
| Block 1 | BC | J | 1 hr - A | 79 | 0.57 | 0.51 |
| Block 1 | BC | J | 1 hr - A | 80 | 0.00 | 1.53 |
| Block 1 | BC | J | 1 hr - A | 81 | 0.84 | 1.01 |
| Block 1 | BC | J | 1 hr - D | 82 | 0.88 | 1.53 |
| Block 1 | BC | J | 1 hr - D | 83 | 0.52 | 2.10 |
| Block 1 | BC | J | 1 hr - D | 84 | 0.05 | 0.84 |
| Block 1 | BC | J | 6 hr - A | 85 | 2.17 | 0.79 |
| Block 1 | BC | J | 6 hr - A | 86 | 1.20 | 0.67 |
| Block 1 | BC | J | 6 hr - A | 87 | 0.26 | 0.39 |
| Block 1 | BC | J | 6 hr - D | 88 | 0.63 | 0.74 |
| Block 1 | BC | J | 6 hr - D | 89 | 0.57 | 0.91 |
| Block 1 | BC | J | 6 hr - D | 90 | 0.19 | 0.94 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate uM | Nitrite uM |
|---|---|---|---|---|---|---|
| Block 2 | F | W | 0 hr - A | 91 | 1.18 | 0.77 |
| Block 2 | F | W | 0 hr - A | 92 | 1.39 | 0.82 |
| Block 2 | F | W | 0 hr - A | 93 | 0.33 | 0.77 |
| Block 2 | F | W | 1 hr - A | 94 | 0.93 | 0.62 |
| Block 2 | F | W | 1 hr - A | 95 | 7.96 | 1.19 |
| Block 2 | F | W | 1 hr - A | 96 | 1.13 | 0.87 |
| Block 2 | F | W | 1 hr - D | 97 | 2.44 | 0.57 |
| Block 2 | F | W | 1 hr - D | 98 | 0.88 | 0.76 |
| Block 2 | F | W | 1 hr - D | 99 | 3.89 | 0.82 |
| Block 2 | F | W | 6 hr - A | 100 | 2.20 | 0.66 |
| Block 2 | F | W | 6 hr - A | 101 | 0.87 | 0.39 |
| Block 2 | F | W | 6 hr - A | 102 | 6.08 | 0.47 |
| Block 2 | F | W | 6 hr - D | 103 | 2.73 | 0.61 |
| Block 2 | F | W | 6 hr - D | 104 | 1.43 | 0.44 |
| Block 2 | F | W | 6 hr - D | 105 | 1.97 | 0.67 |
| Block 2 | F | J | 0 hr - A | 106 | 0.45 | 1.21 |
| Block 2 | F | J | 0 hr - A | 107 | 0.78 | 1.09 |
| Block 2 | F | J | 0 hr - A | 108 | 0.52 | 0.66 |
| Block 2 | F | J | 1 hr - A | 109 | 1.13 | 0.74 |
| Block 2 | F | J | 1 hr - A | 110 | 1.33 | 0.54 |
| Block 2 | F | J | 1 hr - A | 111 | 0.59 | 0.49 |
| Block 2 | F | J | 1 hr - D | 112 | 2.75 | 0.64 |
| Block 2 | F | J | 1 hr - D | 113 | 1.46 | 0.62 |
| Block 2 | F | J | 1 hr - D | 114 | 0.90 | 0.52 |
| Block 2 | F | J | 6 hr - A | 115 | 0.47 | 0.79 |
| Block 2 | F | J | 6 hr - A | 116 | 1.42 | 0.61 |
| Block 2 | F | J | 6 hr - A | 117 | 0.82 | 0.52 |
| Block 2 | F | J | 6 hr - D | 118 | 2.80 | 0.27 |
| Block 2 | F | J | 6 hr - D | 119 | 2.72 | 0.41 |
| Block 2 | F | J | 6 hr - D | 120 | 1.81 | 0.81 |
| Block 2 | BC | W | 0 hr - A | 121 | 4.94 | 0.57 |
| Block 2 | BC | W | 0 hr - A | 122 | 0.57 | 0.77 |
| Block 2 | BC | W | 0 hr - A | 123 | 0.70 | 0.41 |
| Block 2 | BC | W | 1 hr - A | 124 | 1.77 | 1.29 |
| Block 2 | BC | W | 1 hr - A | 125 | 1.55 | 0.96 |
| Block 2 | BC | W | 1 hr - A | 126 | 0.00 | 2.06 |
| Block 2 | BC | W | 1 hr - D | 127 | 2.83 | 1.28 |
| Block 2 | BC | W | 1 hr - D | 128 | 2.26 | 0.36 |
| Block 2 | BC | W | 1 hr - D | 129 | 0.70 | 0.51 |
| Block 2 | BC | W | 6 hr - A | 130 | 4.17 | 0.84 |
| Block 2 | BC | W | 6 hr - A | 131 | 1.89 | 0.94 |
| Block 2 | BC | W | 6 hr - A | 132 | 1.37 | 0.79 |
| Block 2 | BC | W | 6 hr - D | 133 | 0.93 | 0.41 |
| Block 2 | BC | W | 6 hr - D | 134 | 2.62 | 0.74 |
| Block 2 | BC | W | 6 hr - D | 135 | 0.87 | 0.98 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate uM | Nitrite uM |
|---|---|---|---|---|---|---|
| Block 2 | BC | J | 0 hr - A | 136 | 0.43 | 1.86 |
| Block 2 | BC | J | 0 hr - A | 137 | 0.90 | 0.71 |
| Block 2 | BC | J | 0 hr - A | 138 | 0.20 | 1.19 |
| Block 2 | BC | J | 1 hr - A | 139 | 0.26 | 1.16 |
| Block 2 | BC | J | 1 hr - A | 140 | 0.02 | 1.06 |
| Block 2 | BC | J | 1 hr - A | 141 | 1.00 | 0.98 |
| Block 2 | BC | J | 1 hr - D | 142 | 1.07 | 1.91 |
| Block 2 | BC | J | 1 hr - D | 143 | 2.32 | 0.59 |
| Block 2 | BC | J | 1 hr - D | 144 | 1.00 | 0.98 |
| Block 2 | BC | J | 6 hr - A | 145 | 0.61 | 1.21 |
| Block 2 | BC | J | 6 hr - A | 146 | 1.37 | 0.61 |
| Block 2 | BC | J | 6 hr - A | 147 | 2.70 | 0.56 |
| Block 2 | BC | J | 6 hr - D | 148 | 1.57 | 0.94 |
| Block 2 | BC | J | 6 hr - D | 149 | 2.16 | 0.37 |
| Block 2 | BC | J | 6 hr - D | 150 | 1.27 | 0.76 |
| Block 2 | C | W | 0 hr - A | 151 | 4.18 | 0.72 |
| Block 2 | C | W | 0 hr - A | 152 | 4.21 | 0.96 |
| Block 2 | C | W | 0 hr - A | 153 | 15.22 | 0.93 |
| Block 2 | C | W | 1 hr - A | 154 | 2.91 | 0.87 |
| Block 2 | C | W | 1 hr - A | 155 | 3.43 | 0.81 |
| Block 2 | C | W | 1 hr - A | 156 | 7.10 | 0.66 |
| Block 2 | C | W | 1 hr - D | 157 | 0.23 | 0.39 |
| Block 2 | C | W | 1 hr - D | 158 | 2.53 | 0.36 |
| Block 2 | C | W | 1 hr - D | 159 | 0.51 | 1.23 |
| Block 2 | C | W | 6 hr - A | 160 | 8.74 | 0.66 |
| Block 2 | C | W | 6 hr - A | 161 | 4.97 | 0.49 |
| Block 2 | C | W | 6 hr - A | 162 | 2.89 | 0.39 |
| Block 2 | C | W | 6 hr - D | 163 | 1.06 | 0.36 |
| Block 2 | C | W | 6 hr - D | 164 | 1.54 | 0.44 |
| Block 2 | C | W | 6 hr - D | 165 | 1.18 | 0.82 |
| Block 2 | C | J | 0 hr - A | 166 | 0.73 | 1.09 |
| Block 2 | C | J | 0 hr - A | 167 | 0.85 | 1.34 |
| Block 2 | C | J | 0 hr - A | 168 | 2.30 | 1.51 |
| Block 2 | C | J | 1 hr - A | 169 | 1.40 | 1.06 |
| Block 2 | C | J | 1 hr - A | 170 | 2.36 | 1.16 |
| Block 2 | C | J | 1 hr - A | 171 | 11.82 | 0.79 |
| Block 2 | C | J | 1 hr - D | 172 | 0.48 | 0.94 |
| Block 2 | C | J | 1 hr - D | 173 | 1.28 | 0.81 |
| Block 2 | C | J | 1 hr - D | 174 | 1.31 | 0.46 |
| Block 2 | C | J | 6 hr - A | 175 | 1.52 | 1.09 |
| Block 2 | C | J | 6 hr - A | 176 | 0.72 | 1.39 |
| Block 2 | C | J | 6 hr - A | 177 | 1.25 | 1.08 |
| Block 2 | C | J | 6 hr - D | 178 | 0.37 | 0.76 |
| Block 2 | C | J | 6 hr - D | 179 | 1.29 | 0.56 |
| Block 2 | C | J | 6 hr - D | 180 | no sample | no sample |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate uM | Nitrite uM |
|---|---|---|---|---|---|---|
| Block 3 | BC | W | 0 hr - A | 181 | 1.01 | 0.69 |
| Block 3 | BC | W | 0 hr - A | 182 | 1.60 | 0.86 |
| Block 3 | BC | W | 0 hr - A | 183 | 1.00 | 0.87 |
| Block 3 | BC | W | 1 hr - A | 184 | 0.92 | 0.52 |
| Block 3 | BC | W | 1 hr - A | 185 | 1.26 | 0.56 |
| Block 3 | BC | W | 1 hr - A | 186 | 0.72 | 0.81 |
| Block 3 | BC | W | 1 hr - D | 187 | 0.99 | 0.59 |
| Block 3 | BC | W | 1 hr - D | 188 | 1.20 | 1.63 |
| Block 3 | BC | W | 1 hr - D | 189 | 1.23 | 0.77 |
| Block 3 | BC | W | 6 hr - A | 190 | 0.43 | 1.04 |
| Block 3 | BC | W | 6 hr - A | 191 | 0.73 | 1.01 |
| Block 3 | BC | W | 6 hr - A | 192 | 0.67 | 1.13 |
| Block 3 | BC | W | 6 hr - D | 193 | 0.61 | 0.81 |
| Block 3 | BC | W | 6 hr - D | 194 | 0.65 | 1.19 |
| Block 3 | BC | W | 6 hr - D | 195 | 0.95 | 0.84 |
| Block 3 | BC | J | 0 hr - A | 196 | 1.01 | 1.31 |
| Block 3 | BC | J | 0 hr - A | 197 | 1.80 | 0.79 |
| Block 3 | BC | J | 0 hr - A | 198 | 1.54 | 1.13 |
| Block 3 | BC | J | 1 hr - A | 199 | 1.48 | 0.61 |
| Block 3 | BC | J | 1 hr - A | 200 | 0.62 | 0.72 |
| Block 3 | BC | J | 1 hr - A | 201 | 1.07 | 0.54 |
| Block 3 | BC | J | 1 hr - D | 202 | 2.26 | 0.72 |
| Block 3 | BC | J | 1 hr - D | 203 | 0.84 | 0.74 |
| Block 3 | BC | J | 1 hr - D | 204 | 0.66 | 1.11 |
| Block 3 | BC | J | 6 hr - A | 205 | 0.51 | 1.23 |
| Block 3 | BC | J | 6 hr - A | 206 | 0.71 | 0.89 |
| Block 3 | BC | J | 6 hr - A | 207 | no sample | no sample |
| Block 3 | BC | J | 6 hr - D | 208 | 2.25 | 0.74 |
| Block 3 | BC | J | 6 hr - D | 209 | 2.64 | 0.64 |
| Block 3 | BC | J | 6 hr - D | 210 | 0.70 | 1.33 |
| Block 3 | C | W | 0 hr - A | 211 | 1.61 | 0.61 |
| Block 3 | C | W | 0 hr - A | 212 | 1.85 | 0.56 |
| Block 3 | C | W | 0 hr - A | 213 | 1.08 | 0.24 |
| Block 3 | C | W | 1 hr - A | 214 | no sample | no sample |
| Block 3 | C | W | 1 hr - A | 215 | 1.06 | 0.32 |
| Block 3 | C | W | 1 hr - A | 216 | 1.14 | 0.31 |
| Block 3 | C | W | 1 hr - D | 217 | 0.88 | 0.49 |
| Block 3 | C | W | 1 hr - D | 218 | 1.08 | 0.42 |
| Block 3 | C | W | 1 hr - D | 219 | 1.52 | 0.99 |
| Block 3 | C | W | 6 hr - A | 220 | 0.99 | 0.64 |
| Block 3 | C | W | 6 hr - A | 221 | 1.89 | 0.76 |
| Block 3 | C | W | 6 hr - A | 222 | 0.76 | 0.98 |
| Block 3 | C | W | 6 hr - D | 223 | no sample | no sample |
| Block 3 | C | W | 6 hr - D | 224 | 1.19 | 0.52 |
| Block 3 | C | W | 6 hr - D | 225 | 1.02 | 0.74 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Nitrate uM | Nitrite uM |
|---|---|---|---|---|---|---|
| Block 3 | C | J | 0 hr - A | 226 | 2.08 | 0.32 |
| Block 3 | C | J | 0 hr - A | 227 | 0.53 | 0.81 |
| Block 3 | C | J | 0 hr - A | 228 | 1.19 | 0.39 |
| Block 3 | C | J | 1 hr - A | 229 | 0.56 | 0.59 |
| Block 3 | C | J | 1 hr - A | 230 | 1.55 | 0.82 |
| Block 3 | C | J | 1 hr - A | 231 | 0.76 | 0.61 |
| Block 3 | C | J | 1 hr - D | 232 | no sample | no sample |
| Block 3 | C | J | 1 hr - D | 233 | 0.65 | 0.61 |
| Block 3 | C | J | 1 hr - D | 234 | 1.65 | 0.62 |
| Block 3 | C | J | 6 hr - A | 235 | 0.81 | 0.56 |
| Block 3 | C | J | 6 hr - A | 236 | 0.50 | 0.84 |
| Block 3 | C | J | 6 hr - A | 237 | 4.82 | 10.06 |
| Block 3 | C | J | 6 hr - D | 238 | 0.89 | 0.69 |
| Block 3 | C | J | 6 hr - D | 239 | 1.08 | 0.52 |
| Block 3 | C | J | 6 hr - D | 240 | no sample | no sample |
| Block 3 | F | W | 0 hr - A | 241 | 1.73 | 1.73 |
| Block 3 | F | W | 0 hr - A | 242 | 2.73 | 2.73 |
| Block 3 | F | W | 0 hr - A | 243 | 1.54 | 1.54 |
| Block 3 | F | W | 1 hr - A | 244 | 5.75 | 5.75 |
| Block 3 | F | W | 1 hr - A | 245 | 2.90 | 2.90 |
| Block 3 | F | W | 1 hr - A | 246 | 3.03 | 3.03 |
| Block 3 | F | W | 1 hr - D | 247 | 3.13 | 3.13 |
| Block 3 | F | W | 1 hr - D | 248 | 3.51 | 3.51 |
| Block 3 | F | W | 1 hr - D | 249 | 0.76 | 0.76 |
| Block 3 | F | W | 6 hr - A | 250 | 1.33 | 1.33 |
| Block 3 | F | W | 6 hr - A | 251 | 0.00 | 0.00 |
| Block 3 | F | W | 6 hr - A | 252 | 2.89 | 2.89 |
| Block 3 | F | W | 6 hr - D | 253 | 0.99 | 0.99 |
| Block 3 | F | W | 6 hr - D | 254 | 1.18 | 1.18 |
| Block 3 | F | W | 6 hr - D | 255 | 0.80 | 0.80 |
| Block 3 | F | J | 0 hr - A | 256 | 1.71 | 1.72 |
| Block 3 | F | J | 0 hr - A | 257 | 1.65 | 1.65 |
| Block 3 | F | J | 0 hr - A | 258 | 0.69 | 0.69 |
| Block 3 | F | J | 1 hr - A | 259 | 1.19 | 1.19 |
| Block 3 | F | J | 1 hr - A | 260 | 2.03 | 2.03 |
| Block 3 | F | J | 1 hr - A | 261 | 0.87 | 0.87 |
| Block 3 | F | J | 1 hr - D | 262 | no sample | no sample |
| Block 3 | F | J | 1 hr - D | 263 | 2.49 | 2.49 |
| Block 3 | F | J | 1 hr - D | 264 | no sample | no sample |
| Block 3 | F | J | 6 hr - A | 265 | 0.57 | 0.57 |
| Block 3 | F | J | 6 hr - A | 266 | 1.28 | 1.28 |
| Block 3 | F | J | 6 hr - A | 267 | no sample | no sample |
| Block 3 | F | J | 6 hr - D | 268 | no sample | no sample |
| Block 3 | F | J | 6 hr - D | 269 | no sample | no sample |
| Block 3 | F | J | 6 hr - D | 270 | no sample | no sample |

Table B2: The raw data for August. The table indicates the Block, Flooding condition, Vegetation treatment, Incubation treatment and core number. Flooding treamtnets include flooded (F), border control (BC), and control (C). Vegetation treatments include wrack covered (W) and vegetated areas (J). Incubation treatments include the incubation time (0, 1, or 6 hours) and added liquid--Acetylene (A) or Deionized water (D). The data include ammonium, nitrate, nitrite, and nitrous oxide concentrations.

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM ) | Nitrate ( µM ) | Nitrite ( µM ) | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 1 | C | W | 0 hr - A | 1 | 149.61 | 11.70 | 0.24 | 21.07 |
| Block 1 | C | W | 0 hr - A | 2 | 99.00 | 3.55 | 0.06 | 19.99 |
| Block 1 | C | W | 0 hr - A | 3 | 97.89 | 3.19 | 0.13 | 20.16 |
| Block 1 | C | W | 1 hr - A | 4 | 172.82 | 3.57 | 0.20 | 61.98 |
| Block 1 | C | W | 1 hr - A | 5 | 151.96 | 3.15 | 0.17 | 69.03 |
| Block 1 | C | W | 1 hr - A | 6 | 47.77 | 2.18 | 0.31 | 40.80 |
| Block 1 | C | W | 1 hr - D | 7 | 200.35 | 3.43 | 0.38 | 24.85 |
| Block 1 | C | W | 1 hr - D | 8 | 117.52 | 3.01 | 0.18 | 20.28 |
| Block 1 | C | W | 1 hr - D | 9 | 213.68 | 4.04 | 0.27 | 78.11 |
| Block 1 | C | W | 6 hr - A | 10 | 145.29 | 4.18 | 0.22 | 48.45 |
| Block 1 | C | W | 6 hr - A | 11 | 88.88 | 2.74 | 0.20 | 20.21 |
| Block 1 | C | W | 6 hr - A | 12 | 66.04 | 3.07 | 0.20 | 41.03 |
| Block 1 | C | W | 6 hr - D | 13 | 86.28 | 7.98 | 0.18 | 16.59 |
| Block 1 | C | W | 6 hr - D | 14 | 98.38 | 7.69 | 0.31 | 14.57 |
| Block 1 | C | W | 6 hr - D | 15 | 89.86 | 9.52 | 0.22 | 23.38 |
| Block 1 | C | J | 0 hr - A | 16 | 124.18 | 13.83 | 0.31 | 18.56 |
| Block 1 | C | J | 0 hr - A | 17 | 94.18 | 11.41 | 0.20 | 19.19 |
| Block 1 | C | J | 0 hr - A | 18 | 120.97 | 12.00 | 0.27 | 18.90 |
| Block 1 | C | J | 1 hr - A | 19 | 101.34 | 11.98 | 0.26 | 21.74 |
| Block 1 | C | J | 1 hr - A | 20 | 181.21 | 11.06 | 0.51 | 20.28 |
| Block 1 | C | J | 1 hr - A | 21 | 105.17 | 10.71 | 0.24 | 18.49 |
| Block 1 | C | J | 1 hr - D | 22 | 135.29 | 3.29 | 0.36 | 16.97 |
| Block 1 | C | J | 1 hr - D | 23 | 105.17 | 2.28 | 0.29 | 17.73 |
| Block 1 | C | J | 1 hr - D | 24 | 104.55 | 2.22 | 0.31 | 21.80 |
| Block 1 | C | J | 6 hr - A | 25 | 67.52 | 2.27 | 0.22 | 16.75 |
| Block 1 | C | J | 6 hr - A | 26 | 88.63 | 2.35 | 0.34 | 14.25 |
| Block 1 | C | J | 6 hr - A | 27 | 63.69 | 2.00 | 0.20 | 24.50 |
| Block 1 | C | J | 6 hr - D | 28 | 66.90 | 1.60 | 0.34 | 15.33 |
| Block 1 | C | J | 6 hr - D | 29 | 62.95 | 2.21 | 0.24 | 19.22 |
| Block 1 | C | J | 6 hr - D | 30 | 115.66 | 1.93 | 0.43 | 13.61 |
| Block 1 | F | W | 0 hr - A | 31 | no sample | no sample | no sample | 27.15 |
| Block 1 | F | W | 0 hr - A | 32 | 181.83 | 2.30 | 0.31 | 26.48 |
| Block 1 | F | W | 0 hr - A | 33 | 161.34 | 1.83 | 0.20 | 27.16 |
| Block 1 | F | W | 1 hr - A | 34 | 117.64 | 2.17 | 0.15 | 43.26 |
| Block 1 | F | W | 1 hr - A | 35 | 170.72 | 2.20 | 0.33 | 58.73 |
| Block 1 | F | W | 1 hr - A | 36 | 127.64 | 1.87 | 0.17 | 66.37 |
| Block 1 | F | W | 1 hr - D | 37 | 115.17 | 2.72 | 0.18 | 26.25 |
| Block 1 | F | W | 1 hr - D | 38 | 110.85 | 1.75 | 0.24 | 23.53 |
| Block 1 | F | W | 1 hr - D | 39 | 39.00 | 2.17 | 0.15 | 20.97 |
| Block 1 | F | W | 6 hr - A | 40 | 107.39 | 2.01 | 0.18 | 42.05 |
| Block 1 | F | W | 6 hr - A | 41 | 182.57 | 2.09 | 0.27 | 54.07 |
| Block 1 | F | W | 6 hr - A | 42 | 82.33 | 2.15 | 0.13 | 41.04 |
| Block 1 | F | W | 6 hr - D | 43 | 103.69 | 2.38 | 0.15 | 16.85 |
| Block 1 | F | W | 6 hr - D | 44 | 148.62 | 1.97 | 0.31 | 15.19 |
| Block 1 | F | W | 6 hr - D | 45 | 89.00 | 1.94 | 0.26 | 18.08 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium uM | Nitrate uM | Nitrite uM | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 1 | F | J | 0 hr - A | 46 | 104.55 | 2.10 | 0.31 | 17.24 |
| Block 1 | F | J | 0 hr - A | 47 | 111.71 | 1.42 | 0.24 | 16.82 |
| Block 1 | F | J | 0 hr - A | 48 | 78.51 | 1.44 | 0.26 | 16.04 |
| Block 1 | F | J | 1 hr - A | 49 | 77.89 | 1.68 | 0.31 | 15.33 |
| Block 1 | F | J | 1 hr - A | 50 | 88.88 | 1.62 | 0.29 | 15.28 |
| Block 1 | F | J | 1 hr - A | 51 | 60.36 | 31.19 | 0.36 | 19.46 |
| Block 1 | F | J | 1 hr - D | 52 | 113.69 | 7.87 | 0.51 | 15.16 |
| Block 1 | F | J | 1 hr - D | 53 | 84.31 | 4.37 | 0.15 | 15.39 |
| Block 1 | F | J | 1 hr - D | 54 | 67.27 | 9.00 | 0.29 | 16.23 |
| Block 1 | F | J | 6 hr - A | 55 | 62.58 | 2.17 | 0.65 | 12.24 |
| Block 1 | F | J | 6 hr - A | 56 | 119.74 | 10.22 | 0.43 | 12.12 |
| Block 1 | F | J | 6 hr - A | 57 | 69.37 | 2.56 | 0.26 | 11.20 |
| Block 1 | F | J | 6 hr - D | 58 | 47.89 | 10.18 | 0.84 | 11.70 |
| Block 1 | F | J | 6 hr - D | 59 | 54.68 | 9.76 | 0.93 | 11.95 |
| Block 1 | F | J | 6 hr - D | 60 | 51.47 | 8.18 | 0.99 | 12.04 |
| Block 1 | BC | W | 0 hr - A | 61 | 123.07 | 2.43 | 0.84 | 17.69 |
| Block 1 | BC | W | 0 hr - A | 62 | 131.71 | 1.44 | 0.84 | 17.06 |
| Block 1 | BC | W | 0 hr - A | 63 | 94.93 | 9.65 | 0.26 | 20.10 |
| Block 1 | BC | W | 1 hr - A | 64 | 114.18 | 12.04 | 0.27 | 17.21 |
| Block 1 | BC | W | 1 hr - A | 65 | 99.25 | 2.79 | 0.24 | 16.47 |
| Block 1 | BC | W | 1 hr - A | 66 | 95.67 | 9.19 | 0.18 | 15.24 |
| Block 1 | BC | W | 1 hr - D | 67 | 92.09 | 7.89 | 0.24 | 17.41 |
| Block 1 | BC | W | 1 hr - D | 68 | 283.67 | 2.39 | 0.22 | 20.06 |
| Block 1 | BC | W | 1 hr - D | 69 | 119.74 | 1.36 | 0.22 | 20.30 |
| Block 1 | BC | W | 6 hr - A | 70 | 125.66 | 1.39 | 0.18 | 13.42 |
| Block 1 | BC | W | 6 hr - A | 71 | 106.16 | 2.07 | 0.17 | 14.34 |
| Block 1 | BC | W | 6 hr - A | 72 | 106.65 | 1.78 | 0.13 | 23.92 |
| Block 1 | BC | W | 6 hr - D | 73 | 122.08 | 1.46 | 0.20 | 16.29 |
| Block 1 | BC | W | 6 hr - D | 74 | 101.10 | 1.55 | 0.11 | 13.31 |
| Block 1 | BC | W | 6 hr - D | 75 | 80.85 | 0.98 | 0.09 | 13.56 |
| Block 1 | BC | J | 0 hr - A | 76 | 40.24 | 0.47 | 0.27 | 15.98 |
| Block 1 | BC | J | 0 hr - A | 77 | 90.97 | 1.44 | 0.22 | 16.11 |
| Block 1 | BC | J | 0 hr - A | 78 | 46.53 | 1.82 | 0.26 | 17.07 |
| Block 1 | BC | J | 1 hr - A | 79 | 43.20 | 2.31 | 0.34 | 14.23 |
| Block 1 | BC | J | 1 hr - A | 80 | 47.77 | 1.71 | 0.36 | 14.27 |
| Block 1 | BC | J | 1 hr - A | 81 | 40.24 | 1.04 | 0.13 | 14.58 |
| Block 1 | BC | J | 1 hr - D | 82 | 65.79 | 1.06 | 0.15 | 14.88 |
| Block 1 | BC | J | 1 hr - D | 83 | 45.67 | 0.60 | 0.15 | 14.93 |
| Block 1 | BC | J | 1 hr - D | 84 | 43.08 | 0.95 | 0.11 | 14.74 |
| Block 1 | BC | J | 6 hr - A | 85 | 40.73 | 1.24 | 0.18 | 10.71 |
| Block 1 | BC | J | 6 hr - A | 86 | 48.88 | 0.88 | 0.18 | 12.27 |
| Block 1 | BC | J | 6 hr - A | 87 | 57.27 | 0.99 | 0.11 | 11.86 |
| Block 1 | BC | J | 6 hr - D | 88 | 33.57 | 0.65 | 0.13 | 11.62 |
| Block 1 | BC | J | 6 hr - D | 89 | 43.32 | 1.31 | 0.15 | 10.05 |
| Block 1 | BC | J | 6 hr - D | 90 | 43.57 | 0.83 | 0.17 | 11.62 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium uM | Nitrate uM | Nitrite uM | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 2 | F | W | 0 hr - A | 91 | 48.88 | 0.99 | 0.11 | 13.41 |
| Block 2 | F | W | 0 hr - A | 92 | 119.98 | 0.85 | 0.08 | 16.24 |
| Block 2 | F | W | 0 hr - A | 93 | 102.33 | 1.15 | 0.06 | 13.66 |
| Block 2 | F | W | 1 hr - A | 94 | 48.14 | 0.99 | 0.08 | 12.09 |
| Block 2 | F | W | 1 hr - A | 95 | 73.45 | 0.69 | 0.13 | 15.53 |
| Block 2 | F | W | 1 hr - A | 96 | 183.56 | 0.95 | 0.18 | 25.86 |
| Block 2 | F | W | 1 hr - D | 97 | 101.71 | 1.06 | 0.11 | 12.65 |
| Block 2 | F | W | 1 hr - D | 98 | 89.86 | 1.22 | 0.09 | 14.69 |
| Block 2 | F | W | 1 hr - D | 99 | 122.95 | 1.03 | 0.11 | 16.83 |
| Block 2 | F | W | 6 hr - A | 100 | 102.21 | 1.12 | 0.09 | 12.77 |
| Block 2 | F | W | 6 hr - A | 101 | 82.95 | 0.90 | 0.17 | 16.04 |
| Block 2 | F | W | 6 hr - A | 102 | 106.16 | 0.71 | 0.25 | 19.02 |
| Block 2 | F | W | 6 hr - D | 103 | 71.10 | 0.53 | 0.18 | 15.53 |
| Block 2 | F | W | 6 hr - D | 104 | 86.53 | 0.89 | 0.18 | 22.85 |
| Block 2 | F | W | 6 hr - D | 105 | 108.87 | 0.60 | 0.25 | 18.25 |
| Block 2 | F | J | 0 hr - A | 106 | 61.84 | 0.78 | 0.25 | 11.64 |
| Block 2 | F | J | 0 hr - A | 107 | 78.51 | 0.26 | 0.48 | 11.32 |
| Block 2 | F | J | 0 hr - A | 108 | 83.57 | 0.50 | 0.35 | 11.82 |
| Block 2 | F | J | 1 hr - A | 109 | 35.92 | 1.50 | 0.39 | 11.65 |
| Block 2 | F | J | 1 hr - A | 110 | 70.48 | 1.18 | 0.43 | 12.81 |
| Block 2 | F | J | 1 hr - A | 111 | 73.20 | 0.94 | 0.27 | 9.79 |
| Block 2 | F | J | 1 hr - D | 112 | 54.19 | 1.59 | 0.23 | 10.86 |
| Block 2 | F | J | 1 hr - D | 113 | 81.10 | 0.56 | 0.29 | 10.12 |
| Block 2 | F | J | 1 hr - D | 114 | 77.40 | 1.63 | 0.29 | 9.99 |
| Block 2 | F | J | 6 hr - A | 115 | 37.65 | 1.90 | 0.27 | 10.49 |
| Block 2 | F | J | 6 hr - A | 116 | 60.98 | 2.24 | 0.29 | 10.15 |
| Block 2 | F | J | 6 hr - A | 117 | 60.24 | 1.94 | 0.23 | 10.11 |
| Block 2 | F | J | 6 hr - D | 118 | 65.92 | 1.77 | 0.20 | 9.99 |
| Block 2 | F | J | 6 hr - D | 119 | 39.50 | 1.17 | 0.21 | 10.24 |
| Block 2 | F | J | 6 hr - D | 120 | 55.05 | 1.79 | 0.18 | 10.29 |
| Block 2 | BC | W | 0 hr - A | 121 | 111.34 | 1.01 | 0.27 | 14.71 |
| Block 2 | BC | W | 0 hr - A | 122 | 79.49 | 1.51 | 0.27 | 13.82 |
| Block 2 | BC | W | 0 hr - A | 123 | 101.34 | 2.56 | 0.16 | 16.21 |
| Block 2 | BC | W | 1 hr - A | 124 | 90.36 | 1.21 | 0.18 | 17.25 |
| Block 2 | BC | W | 1 hr - A | 125 | 121.84 | 1.26 | 0.23 | 21.74 |
| Block 2 | BC | W | 1 hr - A | 126 | 164.92 | 1.24 | 0.29 | 17.20 |
| Block 2 | BC | W | 1 hr - D | 127 | 129.00 | 1.25 | 0.21 | 17.70 |
| Block 2 | BC | W | 1 hr - D | 128 | 127.14 | 1.87 | 0.20 | 26.16 |
| Block 2 | BC | W | 1 hr - D | 129 | 136.77 | 1.27 | 0.16 | 18.14 |
| Block 2 | BC | W | 6 hr - A | 130 | 80.36 | 2.39 | 0.21 | 13.31 |
| Block 2 | BC | W | 6 hr - A | 131 | 177.02 | 1.30 | 0.20 | 17.55 |
| Block 2 | BC | W | 6 hr - A | 132 | 68.26 | 1.71 | 0.29 | 13.98 |
| Block 2 | BC | W | 6 hr - D | 133 | 91.10 | 0.54 | 0.27 | 12.56 |
| Block 2 | BC | W | 6 hr - D | 134 | 121.22 | 0.80 | 0.23 | 21.81 |
| Block 2 | BC | W | 6 hr - D | 135 | 165.78 | 1.07 | 0.21 | 28.32 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium uM | Nitrate uM | Nitrite uM | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 2 | BC | J | 0 hr - A | 136 | 42.09 | 0.62 | 0.20 | 12.82 |
| Block 2 | BC | J | 0 hr - A | 137 | 76.41 | 0.83 | 0.35 | 13.52 |
| Block 2 | BC | J | 0 hr - A | 138 | 50.61 | 0.45 | 0.41 | 12.15 |
| Block 2 | BC | J | 1 hr - A | 139 | 39.50 | 1.31 | 0.33 | 11.69 |
| Block 2 | BC | J | 1 hr - A | 140 | 39.00 | 2.19 | 0.31 | 11.59 |
| Block 2 | BC | J | 1 hr - A | 141 | 37.28 | 0.67 | 0.25 | 10.68 |
| Block 2 | BC | J | 1 hr - D | 142 | 39.99 | 0.99 | 0.29 | 11.86 |
| Block 2 | BC | J | 1 hr - D | 143 | 32.34 | 1.46 | 0.25 | 11.74 |
| Block 2 | BC | J | 1 hr - D | 144 | 46.04 | 0.59 | 0.41 | 10.86 |
| Block 2 | BC | J | 6 hr - A | 145 | 40.61 | 0.72 | 0.27 | 11.39 |
| Block 2 | BC | J | 6 hr - A | 146 | 68.88 | 0.79 | 0.31 | 11.22 |
| Block 2 | BC | J | 6 hr - A | 147 | 52.95 | 2.01 | 0.31 | 11.16 |
| Block 2 | BC | J | 6 hr - D | 148 | 51.72 | 2.12 | 0.31 | 10.68 |
| Block 2 | BC | J | 6 hr - D | 149 | 55.92 | 1.49 | 0.29 | 11.02 |
| Block 2 | BC | J | 6 hr - D | 150 | 50.11 | 1.16 | 0.37 | 11.08 |
| Block 2 | C | W | 0 hr - A | 151 | 79.00 | 2.15 | 0.31 | 12.93 |
| Block 2 | C | W | 0 hr - A | 152 | 135.42 | 1.28 | 0.29 | 17.32 |
| Block 2 | C | W | 0 hr - A | 153 | 135.42 | 1.31 | 0.33 | 12.48 |
| Block 2 | C | W | 1 hr - A | 154 | 121.84 | 1.36 | 0.35 | 13.07 |
| Block 2 | C | W | 1 hr - A | 155 | 116.90 | 1.67 | 0.29 | 15.78 |
| Block 2 | C | W | 1 hr - A | 156 | 134.30 | 1.93 | 0.39 | 13.57 |
| Block 2 | C | W | 1 hr - D | 157 | 93.44 | 0.63 | 0.29 | 11.96 |
| Block 2 | C | W | 1 hr - D | 158 | 68.01 | 0.76 | 0.16 | 15.36 |
| Block 2 | C | W | 1 hr - D | 159 | 144.30 | 0.81 | 0.22 | 11.94 |
| Block 2 | C | W | 6 hr - A | 160 | 69.25 | 1.58 | 0.20 | 9.99 |
| Block 2 | C | W | 6 hr - A | 161 | 101.47 | 0.84 | 0.22 | 13.23 |
| Block 2 | C | W | 6 hr - A | 162 | 103.20 | 0.76 | 0.20 | 10.52 |
| Block 2 | C | W | 6 hr - D | 163 | 75.79 | 0.74 | 0.29 | 13.12 |
| Block 2 | C | W | 6 hr - D | 164 | 115.17 | 1.25 | 0.25 | 14.26 |
| Block 2 | C | W | 6 hr - D | 165 | 137.39 | 1.49 | 0.22 | 12.85 |
| Block 2 | C | J | 0 hr - A | 166 | 131.47 | 1.05 | 0.27 | 11.95 |
| Block 2 | C | J | 0 hr - A | 167 | 103.32 | 0.81 | 0.33 | 10.61 |
| Block 2 | C | J | 0 hr - A | 168 | 60.73 | 1.28 | 0.50 | 10.44 |
| Block 2 | C | J | 1 hr - A | 169 | 176.77 | 1.23 | 0.27 | 16.25 |
| Block 2 | C | J | 1 hr - A | 170 | 79.00 | 2.80 | 0.31 | 12.37 |
| Block 2 | C | J | 1 hr - A | 171 | 87.52 | 1.12 | 0.20 | 11.17 |
| Block 2 | C | J | 1 hr - D | 172 | 94.80 | 1.50 | 0.39 | 10.47 |
| Block 2 | C | J | 1 hr - D | 173 | 98.38 | 1.44 | 0.27 | 11.41 |
| Block 2 | C | J | 1 hr - D | 174 | 88.51 | 1.17 | 0.22 | 10.25 |
| Block 2 | C | J | 6 hr - A | 175 | 94.31 | 0.89 | 0.46 | 10.32 |
| Block 2 | C | J | 6 hr - A | 176 | 110.11 | 0.93 | 0.25 | 9.81 |
| Block 2 | C | J | 6 hr - A | 177 | 72.70 | 0.86 | 0.25 | 10.49 |
| Block 2 | C | J | 6 hr - D | 178 | 81.59 | 1.57 | 0.29 | 10.30 |
| Block 2 | C | J | 6 hr - D | 179 | 94.31 | 0.86 | 0.25 | 10.52 |
| Block 2 | C | J | 6 hr - D | 180 | 70.61 | 1.09 | 0.27 | 11.10 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium uM | Nitrate uM | Nitrite uM | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 3 | BC | W | 0 hr - A | 181 | 82.95 | 4.24 | 0.27 | 14.96 |
| Block 3 | BC | W | 0 hr - A | 182 | 64.80 | 1.80 | 0.42 | 21.89 |
| Block 3 | BC | W | 0 hr - A | 183 | 60.61 | 1.65 | 0.31 | 13.55 |
| Block 3 | BC | W | 1 hr - A | 184 | 114.31 | 2.13 | 0.44 | 88.03 |
| Block 3 | BC | W | 1 hr - A | 185 | 144.43 | 1.39 | 0.82 | 97.69 |
| Block 3 | BC | W | 1 hr - A | 186 | 106.53 | 9.21 | 0.84 | 37.24 |
| Block 3 | BC | W | 1 hr - D | 187 | 148.13 | 2.23 | 0.52 | 16.56 |
| Block 3 | BC | W | 1 hr - D | 188 | 176.03 | 25.36 | 0.33 | no sample |
| Block 3 | BC | W | 1 hr - D | 189 | 121.47 | 1.45 | 0.54 | 14.43 |
| Block 3 | BC | W | 6 hr - A | 190 | 116.40 | 1.27 | 0.65 | 26.90 |
| Block 3 | BC | W | 6 hr - A | 191 | 70.85 | 1.97 | 0.57 | 58.59 |
| Block 3 | BC | W | 6 hr - A | 192 | 97.76 | 7.12 | 0.39 | 19.86 |
| Block 3 | BC | W | 6 hr - D | 193 | 104.18 | 2.34 | 0.48 | 15.52 |
| Block 3 | BC | W | 6 hr - D | 194 | 80.73 | 2.05 | 0.59 | 12.30 |
| Block 3 | BC | W | 6 hr - D | 195 | 155.78 | 8.89 | 0.95 | 13.67 |
| Block 3 | BC | J | 0 hr - A | 196 | 66.90 | 2.13 | 0.65 | 12.98 |
| Block 3 | BC | J | 0 hr - A | 197 | 137.39 | 14.96 | 0.82 | 13.11 |
| Block 3 | BC | J | 0 hr - A | 198 | 114.80 | 11.83 | 0.44 | 12.89 |
| Block 3 | BC | J | 1 hr - A | 199 | 152.57 | 15.43 | 1.89 | 12.13 |
| Block 3 | BC | J | 1 hr - A | 200 | 127.64 | 8.95 | 2.10 | 11.37 |
| Block 3 | BC | J | 1 hr - A | 201 | 91.35 | 2.76 | 0.99 | 12.54 |
| Block 3 | BC | J | 1 hr - D | 202 | 67.15 | 3.88 | 0.69 | 12.43 |
| Block 3 | BC | J | 1 hr - D | 203 | 70.98 | 3.33 | 0.57 | 12.31 |
| Block 3 | BC | J | 1 hr - D | 204 | 47.40 | 3.26 | 0.42 | 11.96 |
| Block 3 | BC | J | 6 hr - A | 205 | 49.50 | 2.40 | 0.42 | 10.85 |
| Block 3 | BC | J | 6 hr - A | 206 | 51.47 | 5.55 | 1.46 | 11.29 |
| Block 3 | BC | J | 6 hr - A | 207 | 87.02 | 5.60 | 0.59 | 10.90 |
| Block 3 | BC | J | 6 hr - D | 208 | 56.90 | 7.43 | 0.54 | 10.60 |
| Block 3 | BC | J | 6 hr - D | 209 | 109.24 | 2.12 | 1.06 | 10.95 |
| Block 3 | BC | J | 6 hr - D | 210 | 69.99 | 3.09 | 1.01 | 11.74 |
| Block 3 | C | W | 0 hr - A | 211 | 48.14 | 2.42 | 0.44 | 11.42 |
| Block 3 | C | W | 0 hr - A | 212 | 74.43 | 2.71 | 0.39 | 12.06 |
| Block 3 | C | W | 0 hr - A | 213 | 30.61 | 10.04 | 0.33 | 10.69 |
| Block 3 | C | W | 1 hr - A | 214 | 43.57 | 3.48 | 0.42 | 11.47 |
| Block 3 | C | W | 1 hr - A | 215 | 61.10 | 2.23 | 0.27 | 16.39 |
| Block 3 | C | W | 1 hr - A | 216 | 115.29 | 1.29 | 0.57 | 16.45 |
| Block 3 | C | W | 1 hr - D | 217 | 43.70 | 2.91 | 0.63 | 11.64 |
| Block 3 | C | W | 1 hr - D | 218 | 56.78 | 2.14 | 0.39 | 11.60 |
| Block 3 | C | W | 1 hr - D | 219 | 52.34 | 1.63 | 0.59 | 11.67 |
| Block 3 | C | W | 6 hr - A | 220 | 69.00 | 2.23 | 0.37 | 17.48 |
| Block 3 | C | W | 6 hr - A | 221 | 59.74 | 7.27 | 0.35 | 10.91 |
| Block 3 | C | W | 6 hr - A | 222 | 76.66 | 1.89 | 0.39 | 12.26 |
| Block 3 | C | W | 6 hr - D | 223 | 52.95 | 3.29 | 0.46 | 11.85 |
| Block 3 | C | W | 6 hr - D | 224 | 38.02 | 2.38 | 0.37 | 12.47 |
| Block 3 | C | W | 6 hr - D | 225 | 68.26 | 1.07 | 0.72 | 11.24 |

Table B2: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium uM | Nitrate uM | Nitrite uM | Nitrous Oxide (µmol m^-2 h^-1) |
|---|---|---|---|---|---|---|---|---|
| Block 3 | C | J | 0 hr - A | 226 | 31.60 | 4.35 | 0.48 | 13.76 |
| Block 3 | C | J | 0 hr - A | 227 | 25.80 | 1.16 | 0.59 | 12.04 |
| Block 3 | C | J | 0 hr - A | 228 | 108.38 | 4.02 | 0.69 | 12.00 |
| Block 3 | C | J | 1 hr - A | 229 | 54.56 | 3.02 | 0.27 | 12.05 |
| Block 3 | C | J | 1 hr - A | 230 | 54.43 | 6.32 | 0.31 | 12.20 |
| Block 3 | C | J | 1 hr - A | 231 | 82.33 | 4.65 | 0.35 | 12.58 |
| Block 3 | C | J | 1 hr - D | 232 | 30.24 | 11.06 | 0.25 | 12.01 |
| Block 3 | C | J | 1 hr - D | 233 | 62.46 | 2.08 | 0.35 | 13.38 |
| Block 3 | C | J | 1 hr - D | 234 | 50.61 | 2.43 | 0.39 | no sample |
| Block 3 | C | J | 6 hr - A | 235 | 32.09 | 1.76 | 0.20 | 12.04 |
| Block 3 | C | J | 6 hr - A | 236 | 33.70 | 1.56 | 0.22 | 11.29 |
| Block 3 | C | J | 6 hr - A | 237 | 58.76 | 5.75 | 0.44 | 11.32 |
| Block 3 | C | J | 6 hr - D | 238 | 26.29 | 1.94 | 0.20 | 11.38 |
| Block 3 | C | J | 6 hr - D | 239 | 39.50 | 2.67 | 0.22 | 11.73 |
| Block 3 | C | J | 6 hr - D | 240 | 40.86 | 2.38 | 0.33 | 10.58 |
| Block 3 | F | W | 0 hr - A | 241 | 68.01 | 2.40 | 0.46 | 13.31 |
| Block 3 | F | W | 0 hr - A | 242 | 67.52 | 2.61 | 0.25 | 12.30 |
| Block 3 | F | W | 0 hr - A | 243 | 67.40 | 1.56 | 0.22 | 12.69 |
| Block 3 | F | W | 1 hr - A | 244 | 78.01 | 2.03 | 0.29 | 12.72 |
| Block 3 | F | W | 1 hr - A | 245 | 70.48 | 5.43 | 0.18 | 16.02 |
| Block 3 | F | W | 1 hr - A | 246 | 69.12 | 2.26 | 0.20 | 13.92 |
| Block 3 | F | W | 1 hr - D | 247 | 52.83 | 2.00 | 0.35 | 13.81 |
| Block 3 | F | W | 1 hr - D | 248 | 42.95 | 1.97 | 0.31 | 12.91 |
| Block 3 | F | W | 1 hr - D | 249 | 50.24 | 2.21 | 0.29 | 13.00 |
| Block 3 | F | W | 6 hr - A | 250 | 57.52 | 5.13 | 0.27 | 11.31 |
| Block 3 | F | W | 6 hr - A | 251 | 56.90 | 2.45 | 0.22 | 12.17 |
| Block 3 | F | W | 6 hr - A | 252 | 94.93 | 1.34 | 0.33 | 15.80 |
| Block 3 | F | W | 6 hr - D | 253 | 83.94 | 2.85 | 0.33 | 12.42 |
| Block 3 | F | W | 6 hr - D | 254 | 73.32 | 2.14 | 0.29 | 11.94 |
| Block 3 | F | W | 6 hr - D | 255 | 30.86 | 2.70 | 0.27 | no sample |
| Block 3 | F | J | 0 hr - A | 256 | 25.67 | 3.45 | 0.37 | 13.26 |
| Block 3 | F | J | 0 hr - A | 257 | 40.61 | 2.07 | 0.29 | 11.59 |
| Block 3 | F | J | 0 hr - A | 258 | 42.71 | 2.71 | 0.29 | 11.47 |
| Block 3 | F | J | 1 hr - A | 259 | 59.62 | 2.50 | 0.25 | 11.92 |
| Block 3 | F | J | 1 hr - A | 260 | 55.92 | 2.18 | 0.29 | 12.05 |
| Block 3 | F | J | 1 hr - A | 261 | 66.78 | 2.17 | 0.22 | 11.65 |
| Block 3 | F | J | 1 hr - D | 262 | 31.97 | 1.64 | 0.18 | 11.42 |
| Block 3 | F | J | 1 hr - D | 263 | 42.83 | 2.18 | 0.25 | no sample |
| Block 3 | F | J | 1 hr - D | 264 | 34.07 | 1.44 | 0.31 | 11.55 |
| Block 3 | F | J | 6 hr - A | 265 | 32.83 | 2.51 | 0.20 | 10.15 |
| Block 3 | F | J | 6 hr - A | 266 | 43.57 | 2.05 | 0.20 | 11.25 |
| Block 3 | F | J | 6 hr - A | 267 | 27.77 | 2.20 | 0.27 | 14.99 |
| Block 3 | F | J | 6 hr - D | 268 | 31.10 | 2.28 | 0.29 | 10.28 |
| Block 3 | F | J | 6 hr - D | 269 | 27.52 | 2.48 | 0.16 | 10.88 |
| Block 3 | F | J | 6 hr - D | 270 | 22.71 | 3.23 | 0.31 | 10.18 |

Table B3: The raw data for September. The table indicates the Block, Flooding condition, Vegetation treatment, Incubation treatment and core number. Flooding treamtnets include flooded (F), border control (BC), and control (C). Vegetation treatments include wrack covered (W) and vegetated areas (J). Incubation treatments include the incubation time (0, 1, or 6 hours) and added liquid–Acetylene (A) or Deionized water (D). The data include ammonium, nitrate, nitrite, and nitrous oxide concentrations.

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 1 | C | W | 0 hr - A | 1 | 154.65 | 2.67 | 0.48 | 32.780 |
| Block 1 | C | W | 0 hr - A | 2 | 139.56 | 2.26 | 0.43 | 37.400 |
| Block 1 | C | W | 0 hr - A | 3 | 144.64 | 2.17 | 0.48 | 27.450 |
| Block 1 | C | W | 1 hr - A | 4 | 135.38 | 1.76 | 0.43 | 54.460 |
| Block 1 | C | W | 1 hr - A | 5 | 144.89 | 2.40 | 0.56 | 96.050 |
| Block 1 | C | W | 1 hr - A | 6 | 174.81 | 1.64 | 0.55 | 53.960 |
| Block 1 | C | W | 1 hr - D | 7 | 113.19 | 2.09 | 0.48 | 42.880 |
| Block 1 | C | W | 1 hr - D | 8 | 146.41 | 4.83 | 0.48 | 45.000 |
| Block 1 | C | W | 1 hr - D | 9 | 163.40 | 1.33 | 0.62 | 36.720 |
| Block 1 | C | W | 6 hr - A | 10 | 122.83 | 2.23 | 0.53 | 50.160 |
| Block 1 | C | W | 6 hr - A | 11 | 129.93 | 1.99 | 0.51 | 117.490 |
| Block 1 | C | W | 6 hr - A | 12 | 205.12 | 1.33 | 0.51 | 56.470 |
| Block 1 | C | W | 6 hr - D | 13 | 88.34 | 3.48 | 0.52 | 37.530 |
| Block 1 | C | W | 6 hr - D | 14 | 148.95 | 3.66 | 0.77 | no sample |
| Block 1 | C | W | 6 hr - D | 15 | 145.65 | 2.34 | 0.43 | 38.130 |
| Block 1 | C | J | 0 hr - A | 16 | 113.57 | 1.51 | 0.56 | 33.650 |
| Block 1 | C | J | 0 hr - A | 17 | 86.31 | 1.64 | 0.58 | 33.910 |
| Block 1 | C | J | 0 hr - A | 18 | 201.57 | 1.20 | 0.75 | 32.190 |
| Block 1 | C | J | 1 hr - A | 19 | 180.52 | 1.55 | 0.64 | 34.350 |
| Block 1 | C | J | 1 hr - A | 20 | 159.60 | 1.77 | 0.65 | 32.060 |
| Block 1 | C | J | 1 hr - A | 21 | 155.67 | 1.27 | 0.57 | 39.660 |
| Block 1 | C | J | 1 hr - D | 22 | 129.04 | 1.24 | 0.56 | 37.350 |
| Block 1 | C | J | 1 hr - D | 23 | 136.27 | 1.15 | 0.65 | 31.660 |
| Block 1 | C | J | 1 hr - D | 24 | 70.84 | 2.40 | 0.48 | 33.090 |
| Block 1 | C | J | 6 hr - A | 25 | 88.97 | 1.42 | 0.42 | 17.700 |
| Block 1 | C | J | 6 hr - A | 26 | 68.43 | 3.58 | 0.49 | 30.320 |
| Block 1 | C | J | 6 hr - A | 27 | 102.54 | 6.71 | 0.61 | 20.100 |
| Block 1 | C | J | 6 hr - D | 28 | 119.40 | 1.77 | 0.49 | 30.950 |
| Block 1 | C | J | 6 hr - D | 29 | 113.95 | 2.19 | 0.69 | 31.500 |
| Block 1 | C | J | 6 hr - D | 30 | 135.13 | 1.13 | 0.70 | 32.100 |
| Block 1 | F | W | 0 hr - A | 31 | 111.80 | 2.99 | 0.58 | 33.950 |
| Block 1 | F | W | 0 hr - A | 32 | 163.53 | 1.02 | 0.58 | 32.280 |
| Block 1 | F | W | 0 hr - A | 33 | 149.33 | 1.49 | 0.73 | 42.700 |
| Block 1 | F | W | 1 hr - A | 34 | 139.44 | 1.50 | 0.45 | 39.400 |
| Block 1 | F | W | 1 hr - A | 35 | 115.22 | 2.48 | 0.86 | 48.960 |
| Block 1 | F | W | 1 hr - A | 36 | 158.71 | 1.38 | 0.53 | 41.570 |
| Block 1 | F | W | 1 hr - D | 37 | 97.59 | 2.02 | 0.82 | 40.080 |
| Block 1 | F | W | 1 hr - D | 38 | 97.85 | 0.99 | 0.69 | 44.510 |
| Block 1 | F | W | 1 hr - D | 39 | 162.01 | 2.28 | 0.68 | 44.720 |
| Block 1 | F | W | 6 hr - A | 40 | 81.24 | 2.05 | 0.32 | 38.340 |
| Block 1 | F | W | 6 hr - A | 41 | 173.67 | 1.18 | 0.58 | 79.780 |
| Block 1 | F | W | 6 hr - A | 42 | 90.87 | 2.23 | 0.53 | 44.130 |
| Block 1 | F | W | 6 hr - D | 43 | 131.07 | 1.39 | 0.68 | 39.180 |
| Block 1 | F | W | 6 hr - D | 44 | 78.83 | 1.97 | 0.52 | 33.720 |
| Block 1 | F | W | 6 hr - D | 45 | 162.01 | 2.27 | 0.61 | 34.220 |

Table B3: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 1 | F | J | 0 hr - A | 46 | 66.66 | 2.32 | 0.36 | 25.370 |
| Block 1 | F | J | 0 hr - A | 47 | 45.23 | 2.14 | 0.62 | 31.160 |
| Block 1 | F | J | 0 hr - A | 48 | 60.82 | 0.18 | 0.69 | 31.830 |
| Block 1 | F | J | 1 hr - A | 49 | 46.62 | 1.33 | 0.47 | 31.160 |
| Block 1 | F | J | 1 hr - A | 50 | 65.64 | 0.69 | 0.38 | 40.490 |
| Block 1 | F | J | 1 hr - A | 51 | 99.37 | 0.60 | 1.16 | 33.330 |
| Block 1 | F | J | 1 hr - D | 52 | 56.26 | 0.92 | 1.03 | 35.520 |
| Block 1 | F | J | 1 hr - D | 53 | 66.78 | 1.06 | 0.66 | 34.540 |
| Block 1 | F | J | 1 hr - D | 54 | 54.74 | 1.84 | 0.73 | 33.710 |
| Block 1 | F | J | 6 hr - A | 55 | 64.50 | 1.23 | 0.38 | 28.410 |
| Block 1 | F | J | 6 hr - A | 56 | 52.96 | 1.38 | 0.69 | 30.080 |
| Block 1 | F | J | 6 hr - A | 57 | 71.35 | 1.52 | 0.74 | 24.300 |
| Block 1 | F | J | 6 hr - D | 58 | 49.29 | 1.30 | 0.81 | 27.400 |
| Block 1 | F | J | 6 hr - D | 59 | 30.77 | 1.79 | 0.66 | 29.780 |
| Block 1 | F | J | 6 hr - D | 60 | 57.78 | 1.41 | 0.92 | 27.900 |
| Block 1 | BC | W | 0 hr - A | 61 | 127.26 | 1.65 | 0.61 | 30.920 |
| Block 1 | BC | W | 0 hr - A | 62 | 120.04 | 2.02 | 0.62 | 29.840 |
| Block 1 | BC | W | 0 hr - A | 63 | 162.01 | 1.25 | 0.86 | 23.270 |
| Block 1 | BC | W | 1 hr - A | 64 | 127.90 | 1.05 | 0.64 | 48.490 |
| Block 1 | BC | W | 1 hr - A | 65 | 192.31 | 0.75 | 0.78 | 92.900 |
| Block 1 | BC | W | 1 hr - A | 66 | 156.68 | 1.18 | 0.96 | 36.110 |
| Block 1 | BC | W | 1 hr - D | 67 | 83.39 | 3.62 | 0.61 | 44.760 |
| Block 1 | BC | W | 1 hr - D | 68 | 119.28 | 3.05 | 0.30 | 44.610 |
| Block 1 | BC | W | 1 hr - D | 69 | 156.30 | 2.72 | 0.86 | 34.710 |
| Block 1 | BC | W | 6 hr - A | 70 | 105.20 | 1.56 | 0.90 | 71.200 |
| Block 1 | BC | W | 6 hr - A | 71 | 174.43 | 0.51 | 1.05 | 82.760 |
| Block 1 | BC | W | 6 hr - A | 72 | 124.09 | 1.35 | 0.87 | 53.970 |
| Block 1 | BC | W | 6 hr - D | 73 | 81.49 | 4.84 | 0.98 | 32.870 |
| Block 1 | BC | W | 6 hr - D | 74 | 201.06 | 0.94 | 0.94 | 28.070 |
| Block 1 | BC | W | 6 hr - D | 75 | 167.71 | 1.90 | 1.21 | 32.380 |
| Block 1 | BC | J | 0 hr - A | 76 | 65.64 | 0.30 | 0.92 | 26.090 |
| Block 1 | BC | J | 0 hr - A | 77 | 52.46 | 1.46 | 0.34 | 29.320 |
| Block 1 | BC | J | 0 hr - A | 78 | 41.30 | 1.21 | 0.74 | 30.430 |
| Block 1 | BC | J | 1 hr - A | 79 | 48.02 | 1.06 | 0.82 | 31.160 |
| Block 1 | BC | J | 1 hr - A | 80 | 52.20 | 0.70 | 0.52 | 30.160 |
| Block 1 | BC | J | 1 hr - A | 81 | 58.54 | 0.58 | 0.56 | 30.900 |
| Block 1 | BC | J | 1 hr - D | 82 | 48.91 | 1.99 | 2.01 | 31.810 |
| Block 1 | BC | J | 1 hr - D | 83 | 52.08 | 1.51 | 0.44 | 30.800 |
| Block 1 | BC | J | 1 hr - D | 84 | 41.17 | 1.27 | 0.38 | 33.920 |
| Block 1 | BC | J | 6 hr - A | 85 | 41.43 | 0.81 | 0.30 | 24.900 |
| Block 1 | BC | J | 6 hr - A | 86 | 39.02 | 1.73 | 0.42 | 17.560 |
| Block 1 | BC | J | 6 hr - A | 87 | 25.83 | 3.11 | 0.58 | 27.010 |
| Block 1 | BC | J | 6 hr - D | 88 | 60.44 | 1.20 | 0.56 | 26.900 |
| Block 1 | BC | J | 6 hr - D | 89 | 37.62 | 1.23 | 0.38 | 34.800 |
| Block 1 | BC | J | 6 hr - D | 90 | 37.11 | 0.87 | 0.58 | 27.610 |

Table B3: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 2 | F | W | 0 hr - A | 91 | 46.50 | 2.19 | 0.59 | 16.710 |
| Block 2 | F | W | 0 hr - A | 92 | 59.30 | 2.03 | 0.65 | 16.030 |
| Block 2 | F | W | 0 hr - A | 93 | 83.01 | 4.59 | 1.90 | 31.860 |
| Block 2 | F | W | 1 hr - A | 94 | 81.87 | 2.01 | 0.85 | 14.900 |
| Block 2 | F | W | 1 hr - A | 95 | 122.45 | 0.48 | 0.65 | 35.970 |
| Block 2 | F | W | 1 hr - A | 96 | 127.77 | 0.87 | 0.83 | 24.210 |
| Block 2 | F | W | 1 hr - D | 97 | 30.52 | 1.63 | 0.36 | 16.610 |
| Block 2 | F | W | 1 hr - D | 98 | 100.76 | 1.31 | 0.68 | 17.300 |
| Block 2 | F | W | 1 hr - D | 99 | 201.31 | 2.04 | 0.70 | 16.680 |
| Block 2 | F | W | 6 hr - A | 100 | 38.76 | 1.07 | 0.45 | 13.810 |
| Block 2 | F | W | 6 hr - A | 101 | 73.50 | 0.70 | 0.65 | 27.050 |
| Block 2 | F | W | 6 hr - A | 102 | 198.02 | 0.02 | 2.51 | 15.150 |
| Block 2 | F | W | 6 hr - D | 103 | 49.29 | 0.60 | 1.32 | 14.750 |
| Block 2 | F | W | 6 hr - D | 104 | 130.18 | 0.45 | 1.68 | 15.090 |
| Block 2 | F | W | 6 hr - D | 105 | 153.51 | 1.21 | 1.53 | 68.010 |
| Block 2 | F | J | 0 hr - A | 106 | 69.45 | 0.00 | 1.52 | 14.330 |
| Block 2 | F | J | 0 hr - A | 107 | 19.24 | 0.33 | 1.37 | 14.000 |
| Block 2 | F | J | 0 hr - A | 108 | 8.97 | 0.57 | 1.24 | 14.040 |
| Block 2 | F | J | 1 hr - A | 109 | 54.61 | 0.44 | 1.12 | 13.570 |
| Block 2 | F | J | 1 hr - A | 110 | 51.70 | 0.57 | 1.17 | 13.220 |
| Block 2 | F | J | 1 hr - A | 111 | 40.03 | 0.64 | 1.24 | 13.180 |
| Block 2 | F | J | 1 hr - D | 112 | 86.56 | 0.19 | 1.48 | 13.170 |
| Block 2 | F | J | 1 hr - D | 113 | 62.22 | 0.74 | 1.64 | 12.820 |
| Block 2 | F | J | 1 hr - D | 114 | 78.07 | 0.49 | 1.17 | 13.650 |
| Block 2 | F | J | 6 hr - A | 115 | 48.91 | 0.11 | 1.37 | 12.320 |
| Block 2 | F | J | 6 hr - A | 116 | 31.92 | 0.26 | 1.04 | 13.040 |
| Block 2 | F | J | 6 hr - A | 117 | 58.80 | 0.33 | 1.37 | 14.050 |
| Block 2 | F | J | 6 hr - D | 118 | 38.00 | 0.58 | 1.12 | 12.960 |
| Block 2 | F | J | 6 hr - D | 119 | 38.38 | 0.55 | 1.19 | 12.790 |
| Block 2 | F | J | 6 hr - D | 120 | 51.95 | 1.43 | 1.28 | 11.880 |
| Block 2 | BC | W | 0 hr - A | 121 | 57.78 | 1.00 | 1.10 | 15.590 |
| Block 2 | BC | W | 0 hr - A | 122 | 54.10 | 2.56 | 1.23 | 15.620 |
| Block 2 | BC | W | 0 hr - A | 123 | 51.70 | 0.00 | 1.39 | 13.300 |
| Block 2 | BC | W | 1 hr - A | 124 | 97.98 | 0.00 | 1.24 | 18.480 |
| Block 2 | BC | W | 1 hr - A | 125 | 99.37 | 0.00 | 1.26 | 15.860 |
| Block 2 | BC | W | 1 hr - A | 126 | 83.39 | 0.00 | 1.12 | 11.340 |
| Block 2 | BC | W | 1 hr - D | 127 | 94.93 | 0.78 | 1.17 | 15.680 |
| Block 2 | BC | W | 1 hr - D | 128 | 98.99 | 0.84 | 1.15 | 17.730 |
| Block 2 | BC | W | 1 hr - D | 129 | 100.00 | 0.76 | 1.23 | 14.020 |
| Block 2 | BC | W | 6 hr - A | 130 | 92.02 | 0.00 | 1.01 | 14.840 |
| Block 2 | BC | W | 6 hr - A | 131 | 118.01 | 0.00 | 1.01 | 12.740 |
| Block 2 | BC | W | 6 hr - A | 132 | 89.86 | 0.00 | 1.10 | 17.930 |
| Block 2 | BC | W | 6 hr - D | 133 | 107.87 | 0.80 | 1.01 | 12.560 |
| Block 2 | BC | W | 6 hr - D | 134 | 146.66 | 2.97 | 1.39 | 13.390 |
| Block 2 | BC | W | 6 hr - D | 135 | 71.86 | 2.08 | 1.03 | 13.270 |

Table B3: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 2 | BC | J | 0 hr - A | 136 | 12.52 | 0.00 | 1.17 | 17.180 |
| Block 2 | BC | J | 0 hr - A | 137 | 19.36 | 0.00 | 1.14 | 14.050 |
| Block 2 | BC | J | 0 hr - A | 138 | 10.61 | 0.00 | 1.14 | 15.010 |
| Block 2 | BC | J | 1 hr - A | 139 | 37.24 | 0.00 | 1.08 | 13.010 |
| Block 2 | BC | J | 1 hr - A | 140 | 68.94 | 0.00 | 1.32 | 14.050 |
| Block 2 | BC | J | 1 hr - A | 141 | 65.77 | 0.00 | 1.35 | 13.220 |
| Block 2 | BC | J | 1 hr - D | 142 | 32.93 | 0.00 | 1.17 | 13.520 |
| Block 2 | BC | J | 1 hr - D | 143 | 32.68 | 0.00 | 1.19 | 14.710 |
| Block 2 | BC | J | 1 hr - D | 144 | 14.42 | 0.22 | 1.04 | 14.880 |
| Block 2 | BC | J | 6 hr - A | 145 | 28.87 | 0.00 | 1.12 | 12.960 |
| Block 2 | BC | J | 6 hr - A | 146 | 42.31 | 0.00 | 1.14 | 12.750 |
| Block 2 | BC | J | 6 hr - A | 147 | 38.26 | 0.00 | 1.46 | 14.160 |
| Block 2 | BC | J | 6 hr - D | 148 | 30.14 | 0.24 | 0.99 | 12.130 |
| Block 2 | BC | J | 6 hr - D | 149 | 39.65 | 0.00 | 1.21 | 13.070 |
| Block 2 | BC | J | 6 hr - D | 150 | 33.56 | 0.00 | 1.06 | 12.960 |
| Block 2 | C | W | 0 hr - A | 151 | 38.89 | 0.67 | 1.17 | 14.270 |
| Block 2 | C | W | 0 hr - A | 152 | 81.37 | 1.32 | 1.28 | 14.010 |
| Block 2 | C | W | 0 hr - A | 153 | 91.00 | 1.71 | 1.68 | 14.040 |
| Block 2 | C | W | 1 hr - A | 154 | 94.55 | 0.00 | 1.73 | 25.670 |
| Block 2 | C | W | 1 hr - A | 155 | 123.08 | 0.00 | 1.30 | 32.770 |
| Block 2 | C | W | 1 hr - A | 156 | 163.91 | 0.00 | 1.53 | 22.370 |
| Block 2 | C | W | 1 hr - D | 157 | 100.00 | 0.00 | 1.26 | 14.700 |
| Block 2 | C | W | 1 hr - D | 158 | 141.72 | 0.53 | 1.43 | 17.070 |
| Block 2 | C | W | 1 hr - D | 159 | 208.92 | 0.62 | 1.73 | 15.480 |
| Block 2 | C | W | 6 hr - A | 160 | 155.03 | 0.00 | 1.33 | 26.980 |
| Block 2 | C | W | 6 hr - A | 161 | 73.25 | 0.24 | 1.21 | 30.220 |
| Block 2 | C | W | 6 hr - A | 162 | 191.55 | 0.00 | 1.68 | 16.980 |
| Block 2 | C | W | 6 hr - D | 163 | 96.20 | 0.00 | 1.53 | 13.700 |
| Block 2 | C | W | 6 hr - D | 164 | 118.01 | 0.06 | 1.53 | 14.690 |
| Block 2 | C | W | 6 hr - D | 165 | 88.09 | 0.64 | 1.21 | 13.800 |
| Block 2 | C | J | 0 hr - A | 166 | 20.12 | 0.35 | 1.21 | 15.470 |
| Block 2 | C | J | 0 hr - A | 167 | 63.23 | 2.61 | 1.82 | 15.660 |
| Block 2 | C | J | 0 hr - A | 168 | 36.35 | 2.58 | 1.24 | 15.410 |
| Block 2 | C | J | 1 hr - A | 169 | 68.69 | 0.00 | 1.17 | 17.780 |
| Block 2 | C | J | 1 hr - A | 170 | 135.51 | 0.00 | 1.55 | 15.730 |
| Block 2 | C | J | 1 hr - A | 171 | 159.22 | 0.00 | 1.61 | 15.120 |
| Block 2 | C | J | 1 hr - D | 172 | 65.90 | 0.00 | 1.06 | 16.690 |
| Block 2 | C | J | 1 hr - D | 173 | 85.80 | 0.00 | 1.24 | 14.550 |
| Block 2 | C | J | 1 hr - D | 174 | 159.47 | 0.00 | 1.39 | 15.120 |
| Block 2 | C | J | 6 hr - A | 175 | 85.55 | 0.00 | 1.01 | 14.960 |
| Block 2 | C | J | 6 hr - A | 176 | 86.82 | 0.00 | 1.12 | 14.500 |
| Block 2 | C | J | 6 hr - A | 177 | 72.74 | 0.12 | 1.30 | 15.370 |
| Block 2 | C | J | 6 hr - D | 178 | 63.99 | 0.00 | 1.33 | 13.880 |
| Block 2 | C | J | 6 hr - D | 179 | 86.69 | 0.00 | 1.59 | 13.460 |
| Block 2 | C | J | 6 hr - D | 180 | 125.62 | 0.00 | 1.62 | 13.830 |

Table B3: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 3 | BC | W | 0 hr - A | 181 | 92.02 | 15.63 | 1.00 | 72.200 |
| Block 3 | BC | W | 0 hr - A | 182 | 34.45 | 2.08 | 0.57 | 65.080 |
| Block 3 | BC | W | 0 hr - A | 183 | 88.21 | 10.81 | 0.69 | 67.250 |
| Block 3 | BC | W | 1 hr - A | 184 | 59.43 | 2.57 | 0.71 | 65.150 |
| Block 3 | BC | W | 1 hr - A | 185 | 64.50 | 1.43 | 0.81 | 65.650 |
| Block 3 | BC | W | 1 hr - A | 186 | 68.56 | 2.61 | 0.67 | 73.160 |
| Block 3 | BC | W | 1 hr - D | 187 | 75.66 | 1.32 | 1.26 | 51.160 |
| Block 3 | BC | W | 1 hr - D | 188 | 38.51 | 2.25 | 0.57 | 67.110 |
| Block 3 | BC | W | 1 hr - D | 189 | 80.10 | 6.35 | 0.48 | 69.450 |
| Block 3 | BC | W | 6 hr - A | 190 | 88.97 | 2.45 | 1.04 | 76.100 |
| Block 3 | BC | W | 6 hr - A | 191 | 50.17 | 2.06 | 0.77 | 63.500 |
| Block 3 | BC | W | 6 hr - A | 192 | 82.13 | 2.36 | 1.26 | 170.130 |
| Block 3 | BC | W | 6 hr - D | 193 | 47.26 | 2.97 | 1.06 | 75.290 |
| Block 3 | BC | W | 6 hr - D | 194 | 63.74 | 4.85 | 1.10 | 76.740 |
| Block 3 | BC | W | 6 hr - D | 195 | 80.10 | 4.36 | 1.14 | 81.700 |
| Block 3 | BC | J | 0 hr - A | 196 | 60.44 | 3.74 | 1.96 | 63.690 |
| Block 3 | BC | J | 0 hr - A | 197 | 33.31 | 2.42 | 0.91 | 64.950 |
| Block 3 | BC | J | 0 hr - A | 198 | 49.16 | 1.28 | 1.96 | 66.610 |
| Block 3 | BC | J | 1 hr - A | 199 | 43.20 | 2.13 | 1.57 | 59.580 |
| Block 3 | BC | J | 1 hr - A | 200 | 35.59 | 1.88 | 0.69 | 72.530 |
| Block 3 | BC | J | 1 hr - A | 201 | 56.26 | 1.26 | 1.06 | 60.240 |
| Block 3 | BC | J | 1 hr - D | 202 | 81.11 | 2.79 | 1.45 | 68.830 |
| Block 3 | BC | J | 1 hr - D | 203 | 35.97 | 2.47 | 0.73 | 67.750 |
| Block 3 | BC | J | 1 hr - D | 204 | 41.30 | 2.40 | 1.22 | 65.390 |
| Block 3 | BC | J | 6 hr - A | 205 | 30.77 | 2.84 | 0.65 | 72.000 |
| Block 3 | BC | J | 6 hr - A | 206 | 29.25 | 3.15 | 0.59 | 72.070 |
| Block 3 | BC | J | 6 hr - A | 207 | 40.54 | 1.80 | 1.06 | 69.570 |
| Block 3 | BC | J | 6 hr - D | 208 | 48.40 | 3.69 | 1.43 | 76.760 |
| Block 3 | BC | J | 6 hr - D | 209 | 27.48 | 3.15 | 0.89 | 72.710 |
| Block 3 | BC | J | 6 hr - D | 210 | 35.47 | 3.72 | 1.02 | 70.420 |
| Block 3 | C | W | 0 hr - A | 211 | 29.63 | 4.15 | 1.51 | 55.510 |
| Block 3 | C | W | 0 hr - A | 212 | 34.83 | 4.44 | 1.22 | 58.040 |
| Block 3 | C | W | 0 hr - A | 213 | 31.92 | 3.24 | 1.55 | 56.420 |
| Block 3 | C | W | 1 hr - A | 214 | 50.43 | 3.08 | 1.08 | 61.310 |
| Block 3 | C | W | 1 hr - A | 215 | 40.41 | 3.18 | 1.32 | 59.080 |
| Block 3 | C | W | 1 hr - A | 216 | 40.92 | 2.01 | 1.57 | 60.880 |
| Block 3 | C | W | 1 hr - D | 217 | 64.12 | 2.96 | 1.12 | 63.260 |
| Block 3 | C | W | 1 hr - D | 218 | 62.35 | 1.73 | 1.26 | 56.400 |
| Block 3 | C | W | 1 hr - D | 219 | 75.53 | 3.50 | 1.79 | 57.060 |
| Block 3 | C | W | 6 hr - A | 220 | 49.79 | 3.77 | 1.18 | 61.250 |
| Block 3 | C | W | 6 hr - A | 221 | 51.06 | 2.36 | 1.30 | 64.800 |
| Block 3 | C | W | 6 hr - A | 222 | 57.02 | 1.81 | 1.51 | 70.800 |
| Block 3 | C | W | 6 hr - D | 223 | 60.06 | 3.17 | 0.87 | 72.630 |
| Block 3 | C | W | 6 hr - D | 224 | 84.03 | 3.00 | 1.45 | 68.290 |
| Block 3 | C | W | 6 hr - D | 225 | 61.33 | 4.03 | 1.59 | 65.320 |

Table B3: (continued)

| Block # | Flood Treatment | Vegetation Treat,ment | Incubation Treatment | Core # | Ammonium ( µM) | Nitrate ( µM) | Nitrite ( µM) | Nitrous Oxide ( µmol m^-2 h^-1 ) |
|---|---|---|---|---|---|---|---|---|
| Block 3 | C | J | 0 hr - A | 226 | 24.31 | 1.44 | 0.59 | 54.600 |
| Block 3 | C | J | 0 hr - A | 227 | 43.96 | 2.45 | 2.29 | 54.060 |
| Block 3 | C | J | 0 hr - A | 228 | 30.27 | 5.20 | 1.00 | 53.870 |
| Block 3 | C | J | 1 hr - A | 229 | 26.59 | 0.98 | 0.56 | 64.530 |
| Block 3 | C | J | 1 hr - A | 230 | 45.61 | 1.23 | 1.51 | 53.670 |
| Block 3 | C | J | 1 hr - A | 231 | 49.54 | 1.65 | 1.00 | 63.560 |
| Block 3 | C | J | 1 hr - D | 232 | 34.83 | 0.74 | 0.75 | 61.770 |
| Block 3 | C | J | 1 hr - D | 233 | no sample | no sample | no sample | no sample |
| Block 3 | C | J | 1 hr - D | 234 | 47.26 | 1.43 | 1.14 | 60.140 |
| Block 3 | C | J | 6 hr - A | 235 | 24.56 | 1.22 | 0.81 | 70.310 |
| Block 3 | C | J | 6 hr - A | 236 | 43.71 | 0.63 | 0.65 | 58.400 |
| Block 3 | C | J | 6 hr - A | 237 | 56.26 | 2.22 | 0.77 | 55.510 |
| Block 3 | C | J | 6 hr - D | 238 | 27.60 | 1.63 | 0.40 | 72.500 |
| Block 3 | C | J | 6 hr - D | 239 | 40.28 | 3.11 | 2.43 | 60.870 |
| Block 3 | C | J | 6 hr - D | 240 | 23.17 | 2.34 | 0.98 | 69.340 |
| Block 3 | F | W | 0 hr - A | 241 | 35.97 | 2.72 | 0.73 | 59.620 |
| Block 3 | F | W | 0 hr - A | 242 | 41.81 | 3.98 | 0.81 | 53.210 |
| Block 3 | F | W | 0 hr - A | 243 | 36.99 | 3.33 | 0.79 | 52.290 |
| Block 3 | F | W | 1 hr - A | 244 | 59.56 | 1.27 | 0.59 | 89.100 |
| Block 3 | F | W | 1 hr - A | 245 | 66.91 | 1.03 | 0.75 | 61.720 |
| Block 3 | F | W | 1 hr - A | 246 | 63.11 | 0.54 | 0.87 | 65.880 |
| Block 3 | F | W | 1 hr - D | 247 | 37.75 | 2.87 | 0.42 | 62.510 |
| Block 3 | F | W | 1 hr - D | 248 | 60.32 | 3.24 | 0.71 | 57.480 |
| Block 3 | F | W | 1 hr - D | 249 | 72.49 | 1.15 | 0.67 | 56.230 |
| Block 3 | F | W | 6 hr - A | 250 | 53.85 | 0.69 | 0.97 | 67.690 |
| Block 3 | F | W | 6 hr - A | 251 | 62.60 | 1.34 | 0.69 | 56.790 |
| Block 3 | F | W | 6 hr - A | 252 | 68.69 | 1.61 | 0.67 | 67.960 |
| Block 3 | F | W | 6 hr - D | 253 | 48.02 | 4.81 | 1.14 | 64.440 |
| Block 3 | F | W | 6 hr - D | 254 | 75.91 | 1.09 | 0.73 | 74.620 |
| Block 3 | F | W | 6 hr - D | 255 | 68.05 | 1.68 | 0.73 | 67.200 |
| Block 3 | F | J | 0 hr - A | 256 | 33.06 | 2.13 | 0.95 | 56.140 |
| Block 3 | F | J | 0 hr - A | 257 | 39.27 | 2.83 | 0.50 | 49.070 |
| Block 3 | F | J | 0 hr - A | 258 | 54.61 | 3.60 | 1.10 | 49.560 |
| Block 3 | F | J | 1 hr - A | 259 | 42.83 | 1.35 | 0.81 | 61.620 |
| Block 3 | F | J | 1 hr - A | 260 | 55.37 | 0.23 | 0.97 | 59.270 |
| Block 3 | F | J | 1 hr - A | 261 | 72.49 | 0.57 | 1.00 | 60.610 |
| Block 3 | F | J | 1 hr - D | 262 | 51.95 | 1.60 | 0.56 | 61.500 |
| Block 3 | F | J | 1 hr - D | 263 | 48.02 | 0.43 | 1.10 | 45.520 |
| Block 3 | F | J | 1 hr - D | 264 | 66.40 | 2.07 | 0.59 | 57.420 |
| Block 3 | F | J | 6 hr - A | 265 | 56.01 | 1.24 | 1.08 | 54.240 |
| Block 3 | F | J | 6 hr - A | 266 | 43.71 | 1.60 | 1.18 | 54.310 |
| Block 3 | F | J | 6 hr - A | 267 | 50.43 | 0.44 | 1.26 | 55.770 |
| Block 3 | F | J | 6 hr - D | 268 | 54.10 | 1.83 | 0.54 | 46.300 |
| Block 3 | F | J | 6 hr - D | 269 | 46.50 | 1.16 | 0.79 | 65.630 |
| Block 3 | F | J | 6 hr - D | 270 | 61.20 | 1.19 | 0.63 | 61.770 |

Table B4: The raw data for October. The table indicates the drying treatment--Dry (D) or Wet (W). Incubation treatment includes the incubation time (0, 1, or 6 hours) and added liquid--Acetylene (A) or Deionized water (D). The data include ammonium, nitrate, nitrite, and nitrous oxide concentrations.

| Drying Treatment | Incubation Treatment | Replicate Number | Ammonium ( µM ) | Nitrate ( µM ) | Nitrite ( µM ) | Nitrous Oxide ( umol/m^2 ) |
|---|---|---|---|---|---|---|
| D | 0 - A | 1 | 8.20 | 0.94 | 1.11 | 24.27 |
| D | 0 - A | 2 | 21.13 | 1.37 | 0.78 | 26.45 |
| D | 0 - A | 3 | 13.42 | 0.76 | 0.70 | 25.54 |
| D | 0 - A | 4 | 12.67 | 1.13 | 0.83 | 25.57 |
| D | 1 - A | 1 | 21.75 | 1.23 | 0.79 | 19.73 |
| D | 1 - A | 2 | 24.86 | 0.00 | 1.72 | 20.03 |
| D | 1 - A | 3 | 19.89 | 1.35 | 0.94 | 20.88 |
| D | 1 - A | 4 | 22.62 | 0.37 | 0.91 | 24.39 |
| D | 1 - D | 1 | 5.46 | 0.69 | 0.68 | 23.05 |
| D | 1 - D | 2 | 3.22 | 0.00 | 0.59 | 21.45 |
| D | 1 - D | 3 | 30.96 | 0.00 | 0.57 | 24.54 |
| D | 1 - D | 4 | 7.20 | 0.97 | 0.46 | 20.67 |
| D | 6 - A | 1 | 21.38 | 0.00 | 0.63 | 14.08 |
| D | 6 - A | 2 | 63.05 | 0.00 | 1.06 | 14.31 |
| D | 6 - A | 3 | 21.88 | 0.54 | 0.98 | 14.17 |
| D | 6 - A | 4 | 19.14 | 1.13 | 0.83 | 15.66 |
| D | 6 - D | 1 | 4.59 | 0.00 | 0.91 | 13.96 |
| D | 6 - D | 2 | 4.34 | 0.00 | 0.61 | 12.95 |
| D | 6 - D | 3 | 6.08 | 1.30 | 0.91 | 13.19 |
| D | 6 - D | 4 | 2.60 | 0.00 | 0.76 | 15.77 |
| W | 0 - A | 1 | 6.46 | 0.36 | 0.47 | 25.14 |
| W | 0 - A | 2 | 16.41 | 0.18 | 0.66 | 26.09 |
| W | 0 - A | 3 | 9.32 | 0.00 | 0.46 | 21.77 |
| W | 0 - A | 4 | 23.00 | 0.00 | 1.09 | 19.53 |
| W | 1 - A | 1 | 21.88 | 0.15 | 1.00 | 22.35 |
| W | 1 - A | 2 | 23.62 | 0.00 | 0.81 | 21.44 |
| W | 1 - A | 3 | 20.88 | 0.00 | 0.59 | 20.50 |
| W | 1 - A | 4 | 22.13 | 0.00 | 1.10 | 21.87 |
| W | 1 - D | 1 | 7.57 | 0.00 | 0.46 | 20.77 |
| W | 1 - D | 2 | 14.54 | 0.00 | 0.49 | 25.82 |
| W | 1 - D | 3 | 13.05 | 0.00 | 0.63 | 25.33 |
| W | 1 - D | 4 | 10.81 | 0.00 | 0.40 | 25.06 |
| W | 6 - A | 1 | 8.20 | 0.00 | 0.66 | 14.87 |
| W | 6 - A | 2 | 9.32 | 0.00 | 0.36 | 14.84 |
| W | 6 - A | 3 | 12.67 | 0.00 | 0.63 | 12.84 |
| W | 6 - A | 4 | 14.79 | 0.00 | 0.70 | 14.06 |
| W | 6 - D | 1 | 11.31 | 0.00 | 0.85 | 13.91 |
| W | 6 - D | 2 | 16.90 | 0.01 | 0.79 | 13.66 |
| W | 6 - D | 3 | 15.66 | 0.28 | 0.68 | 14.07 |
| W | 6 - D | 4 | 11.55 | 0.06 | 0.44 | 14.91 |

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