Ecological Engineering 52 (2013) 125–129

Contents lists available at SciVerse ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

The sinks of dissolved inorganic nitrogen in surface water of wetland mesocosms

Yuechen Tan[a], Jing Li[a], Jinwei Cheng[a], Binhe Gu[b,*], Jianming Hong[a,*]

[a] College and Life Science, Capital Normal University, Beijing 100048, China
[b] Soil and Water Science Department, University of Florida, Gainesville, FL 32611, USA

ARTICLE INFO

Article history:
Received 8 August 2012
Received in revised form 8 December 2012
Accepted 9 December 2012
Available online 20 January 2013

Keywords:
Emergent plants
Nitrogen assimilation
Stable isotope labeling
Submerged plants
Wetlands

ABSTRACT

The transport of dissolved inorganic nitrogen in wetlands was investigated in the Yeyahu National Preserve of Beijing, China, from July to December 2011. Stable isotope of nitrogen (^{15}N) as NH_4^+ was added to experimental mesocosms vegetated by seven common wetland plants. The ^{15}N abundance in soil and various plant parts were measured at prescribed time intervals during the 49-day experimental period. Rapid ^{15}N enrichments were found in soil and aquatic plants during the first sampling event at day 3 and typically increased linearly during the experimental period. Highest ^{15}N enrichment was found in submerged plants, followed by emergent plants and soil. No differences in $\delta^{15}N$ values were found among leaves and stems of all submerged plants (*Potamogeton pusillus*, *Potamogeton perfoliatus*, *Najas marina*, *Ceratophyllum demersum*), suggesting that these plant structures are equally effective in nitrogen assimilation. The roots of *P. perfoliatus* displayed the lowest enrichment compared to the stems and leaves. Such results indicate that submerged plant roots may have a relatively weak role in nitrogen assimilation. The two emergent plants (*Phragmites australis* and *Typha orientalis*) showed no differences in $\delta^{15}N$ values among all plant parts, suggesting rapid translocation of nitrogen from roots to other portions. This experiment demonstrates that wetland soil and plant stems and leaves are major sinks for dissolved nitrogen from the surface water and provides valuable insight into nitrogen retention and transport pathways in various wetland plants.

1. Introduction

Wetlands improve downstream water quality by intercepting soil, nutrients and other pollutants transported from uplands and upstream aquatic ecosystems (Johnston, 1991). Many recent studies have been performed to evaluate nutrient removal efficiency at the system level (e.g., Jordan et al., 2003; Vymazal, 2007). It is known that dissolved nutrients and particulate pollutants from surface water can be removed by biological assimilation, chemical precipitation and gravitational settlement (Brix, 1994; Kadlec et al., 2000; Dierberg et al., 2002). Yet, there is little available data on nutrient removal pathways among various ecological types of aquatic plants and the magnitude of nutrient removal via specific physical and biogeochemical processes.

Studies on wetland performance of nutrient removal are typically conducted by monitoring changes in surface water nutrient concentrations at inflow and outflow structures (Sartoris et al., 1999; Gu and Dreschel, 2008) or by analyzing the total nutrient budget of major wetland components (Kadlec et al., 2000; Reddy et al., 1993). Such measurements can only provide nutrient removal performance for the wetland system as a whole, and do not provide insight into the pathways of nutrient sequestration or the magnitude of nutrient removal via each mechanism. A detail analysis of major nutrient pools within a wetland is often quite time consuming and labor intensive.

In recent years, stable isotopes have been widely applied to the study of nutrient cycling in aquatic ecosystems. The stable isotope labeling technique could be applied to the study of individual, population, community and the whole ecosystem. This technique often acquires information on nutrient mineralization, microbial decomposition and plant assimilation at time scales from hours to several decades (Nadelhoffer and Fry, 1994; Peterson et al., 1997). Moreover, the stable isotope labeling can be performed at various scales of experimental units, from the microcosm (Wozniak et al., 2008; Li et al., 2010) to the ecosystem level (Pace et al., 2004; Carpenter et al., 2005). To date, related applications have largely focused on lakes (Pace et al., 2004; Carpenter et al., 2005; Li et al., 2010), coastal waters and salt water marsh (White and Howes, 1994; Barrón et al., 2006), and there are only limited studies on freshwater wetlands (Gribsholt et al., 2007; Wozniak et al., 2008).

The objective of this study was to investigate the transfer pathways of dissolved inorganic nitrogen from the surface water of wetland ecosystems. Stable isotope nitrogen tracer (^{15}N) was added to experimental mesocosms vegetated by several species

* Corresponding author.
E-mail address: hjm2910@263.net (J. Hong).

0925-8574/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.ecoleng.2012.12.084

Table 1
Major physical, chemical and biological variables in the wetland study area before the experiment.

Variables	Average ± SD	N
Soil temperature (°C)	17.0 ± 11.4.4	3
Water temperature (°C)	26.0 ± 2.5	12
DO ($mg\,L^{-1}$)	5.01 ± 1.54	44
pH	8.37 ± 0.46	44
Chlorophyll a ($\mu g\,L^{-1}$)	6.87 ± 3.13	48
TN ($mg\,L^{-1}$)	1.59 ± 0.49	44
TP ($mg\,L^{-1}$)	0.067 ± 0.03	44
COD_{cr} ($mg\,L^{-1}$)	32.2 ± 11.3	48

of common submerged and emergent wetland plants. The isotope enrichments in soil and different plant biomass were measured at prescribed time intervals. Study findings provide important information on the pathways and magnitude of nutrient transfer among major components of the wetland ecosystem.

2. Methods

2.1. Study site

This study was conducted at the Yeyahu National Wetland Preserve located in northwestern Beijing, China (115°46′16″–115°59′48″N and 40°22′04″–40°30′31″E). The total area of the preserve is 87 km^2, with a surface water area of 9.8 km^2, and a marsh area of 12 km^2 (Hong et al., 2012). The annual average air temperature is 13.1 °C, and the annual daylight duration is about 2813 h (Wang et al., 2005).

2.2. Mesocosm design

Mesocosms were constructed using PVC cylinders with an inner diameter of 80 cm and a height of 75 cm. In the field, each PVC cylinder was pushed into the soil to a depth of about 20 cm, and the plants and associated benthic organisms were isolated. During this process, thorough efforts were taken to ensure that the communities isolated from the surrounding environment and within the mesocosm were undisturbed. All experiments were initiated the second day after installation. During the study period, water depth was 43.5 ± 4.3 cm (mean ± SD).

A total of 8 mesocosms were installed at selected sites with representative dominant wetland plant species including common reed (*Phragmites australis Cav.*) and cattail (*Typha orientalis* Presl.) as emergent plants, and coontail (*Ceratophyllum demersum* L.), small pondweed (*Potamogeton pusillus* L.) claspingleaf pondweed (*Potamogeton perfoliatus* L.) and spiny naiad (*Najas marina* L.) as submerged plants.

2.3. Water quality analysis and ^{15}N tracer addition

Beginning on August 15, 2011, major physical, chemical and biological variables were either measured in situ or in the laboratory prior to the experiment (Table 1). At the first day of the experiment, the overlying water of each mesocosm was isotopically enriched by adding the ^{15}N tracer, $^{15}NH_4Cl$ (98% ^{15}N, Sigma–Aldrich) at a concentration of 262 $\mu g\ ^{15}N\ L^{-1}$.

2.4. Sample collection and pretreatment

Soil and plant samples were taken prior to ^{15}N addition (day 0), on day 3 and every 7 days subsequently for 7 weeks after ^{15}N addition. The first sampling event on day 0 was done at a pre-selected site without the mesocosm installation. During each sampling event, all plant parts within a mesocosm were harvested. Soil samples were taken with a corer and sectioned at 5 cm intervals (0–5 cm, 5–10 cm and 10–15 cm) in the field. All samples were placed on ice immediately after collection and sent to the laboratory for treatment. Plant parts were separated into roots, rhizomes, stems, old leaves and new leaves, if available, and were cleaned with deionized water. All samples were dried to a constant weight at 70 °C in an oven and were ground into the fine powder that passed the 100-mesh metal sieve. The sample powder was stored securely in centrifuge vials prior to stable isotope analysis.

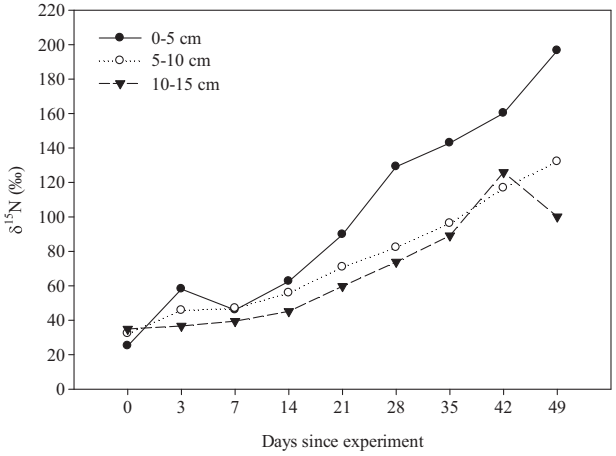

Fig. 1. Time series of $\delta^{15}N$ values of different depth intervals of sediment nitrogen pool during the 49-day mesocosm experiment.

2.5. ^{15}N determination

Stable isotope analysis was performed at the Chinese Academy of Forestry Sciences in Beijing, using an Isotope Ratio Mass Spectrometer (DELTA V Advantage) coupled with an Elemental Analyzer (Flash EA1112 HT). The isotope ratio is expressed in the conventional delta (δ) notation, defined as the per mil (‰) deviation from the isotope standard:

$$\delta^{15}N(‰) = \left(\frac{^{15}N/^{14}N_{sample}}{^{15}N/^{14}N_{standard}} - 1 \right) \times 1000$$

All results are presented with respect to international standard of atmospheric nitrogen (AIR, N_2). Analytical reproducibility based on replicates of internal standards is ± 0.2 ‰ for $\delta^{15}N$.

3. Results

3.1. ^{15}N enrichment in soils

^{15}N enrichment was detected at all depth intervals since the first sampling event at day 3 and increased steadily throughout the whole experiment (Fig. 1). Compared to those at day 0, there was a 7.8, 4.0 and 2.8-fold increase in $\delta^{15}N$ at 0–5 cm, 5–10 cm and 10–15 cm by the end of the experiment (day 49), respectively. The $\delta^{15}N$ values were significantly different among three depth intervals (ANOVA, $p < 0.05$) and the difference became greater with time (Fig. 1). Post hoc analysis (Dunn's method) indicated that the ^{15}N content at the 0–5 cm interval was significantly higher than those at 5–10 cm and 10–15 cm ($p < 0.05$). No significant difference of $\delta^{15}N$ between 5 and 10 cm and 10 and 15 cm was found ($p > 0.05$).