Hydrologic and nutrient dynamics in an unregulated New England floodplain

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Overview

- Non-point source pollution from agriculture is a major source of water quality degradation
- Can lead to eutrophication, anoxia and contamination of drinking water
- Floodplains can act as both sources and sinks of nutrients
- Determine how flooding events impact hydrologic and nutrient dynamics in an agriculturally influenced floodplain

Introduction & Background

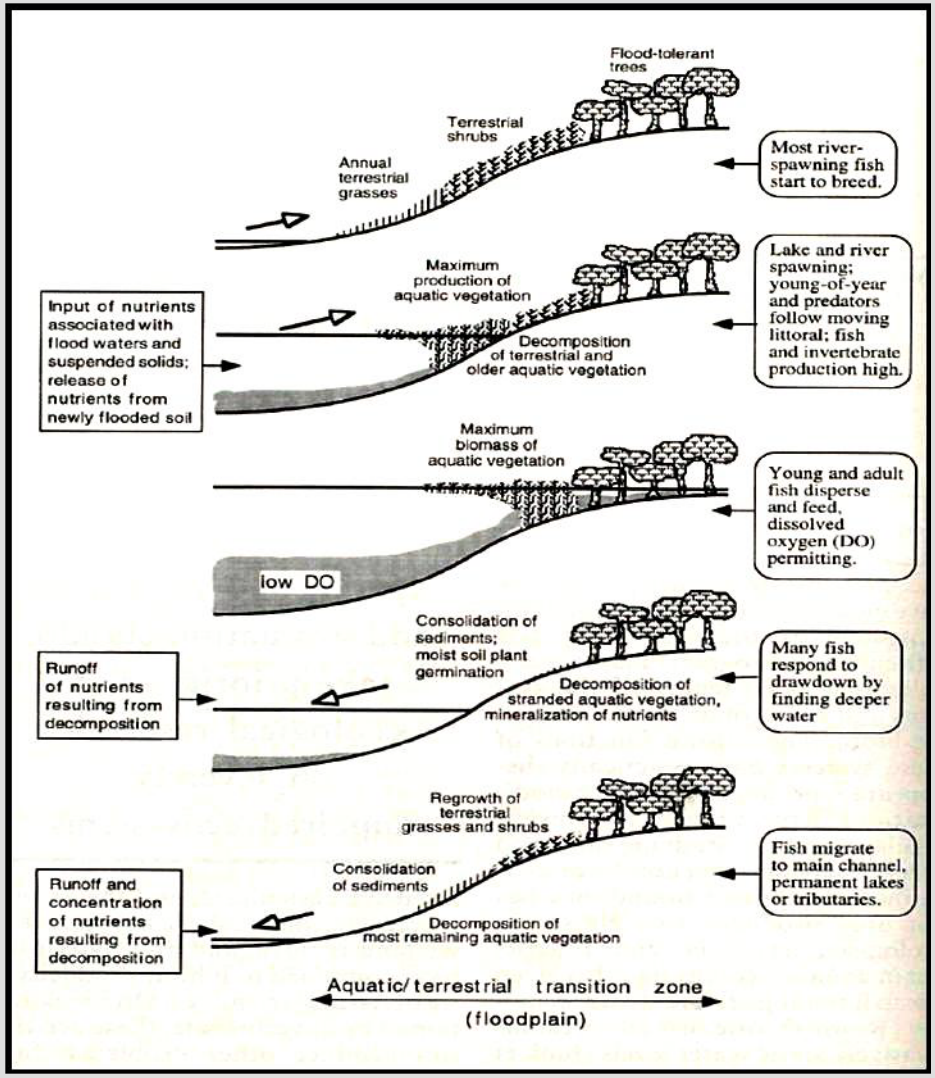
• Floodplains are low-lying areas adjacent to rivers and streams that are subject to periodic inundation and cycles of erosion and deposition (Junk *et al.* 1989)

• Rainfall, overland runoff, upland river and tributary flow and rising groundwater can all contribute to flooding (Tockner et al. 2000)

• One of the most diverse and productive ecosystems (Tockner and Stanford 2002)

•Flooding form a direct link between terrestrial and aquatic ecosystems (Junk *et al*. 1989, Tockner *et al*. 2000).

Introduction & Background



From Bayley 1995 (Adapted from Junk *et al.* 1989)

As river water inundates the floodplain a series of processes occur including:

1. Nutrients and sediments from stream are flushed onto the floodplain (Lewis *et al.* 2000),
2. Terrestrial habitat is flooded and inorganic and organic matter deposited on the surface is mobilized by the water
3. Large amounts of biomass decay (Hamilton *et al*. 1997, Sabo *et al*. 1999).
4. As the water recedes, water in the floodplain and all of the dissolved or suspended matter in it are returned to the river (Benke *et al.* 2000).

Introduction & Background

- Nutrient cycling in the floodplain is significantly influenced by duration, spatial magnitude, variability, frequency and seasonal weather patterns.

- Nutrient cycling, uptake, denitrification potential and rate of decomposition can all be influenced by temporal variability, with slower rates normally occurring in the colder temperatures and faster rates occurring during warmer temperatures (Tockner *et al.* 2000).

- The fall NO_3 pulse is dependent on the summer rainfall regime
  - dry summers, soil NO_3 accumulates
  - wet summer, little NO_3 accumulates

Introduction & Background

- Most studies of long-hydroperiod floodplains have shown surface water decreases in NO_3 and increases in DON and DOP
  - NO_3 attenuation can occur through denitrification, dilution and plant uptake
- There is some variability in whether floodplains are a source or sink of NH_4, particulate N and P, and dissolved reactive P
  - Can be source of P when anoxic soils result in release of P and increases in PO_4

Introduction & Background

- Studies of short-hydroperiod floodplains have shown them to act as NO_3 sources (Noe and Hupp 2000)
    - lack of biological nutrient uptake, lack of oxygen depletion and denitrification, and/or release of NO3- stored in dry floodplain soils

- Lindholm *et al.* (2007) found that in small flood events, there were higher concentrations of nutrients (N and P) and higher primary productivity than during large flood events.
    - Lower dilution of stored nutrients

Justification for Research

- No singular response of nutrient behavior and cycling (e.g., inorganic nutrient release versus retention) and ecological activity to inundation in river-floodplain systems
- Few floodplain studies have been conducted in agricultural landscapes or in New England

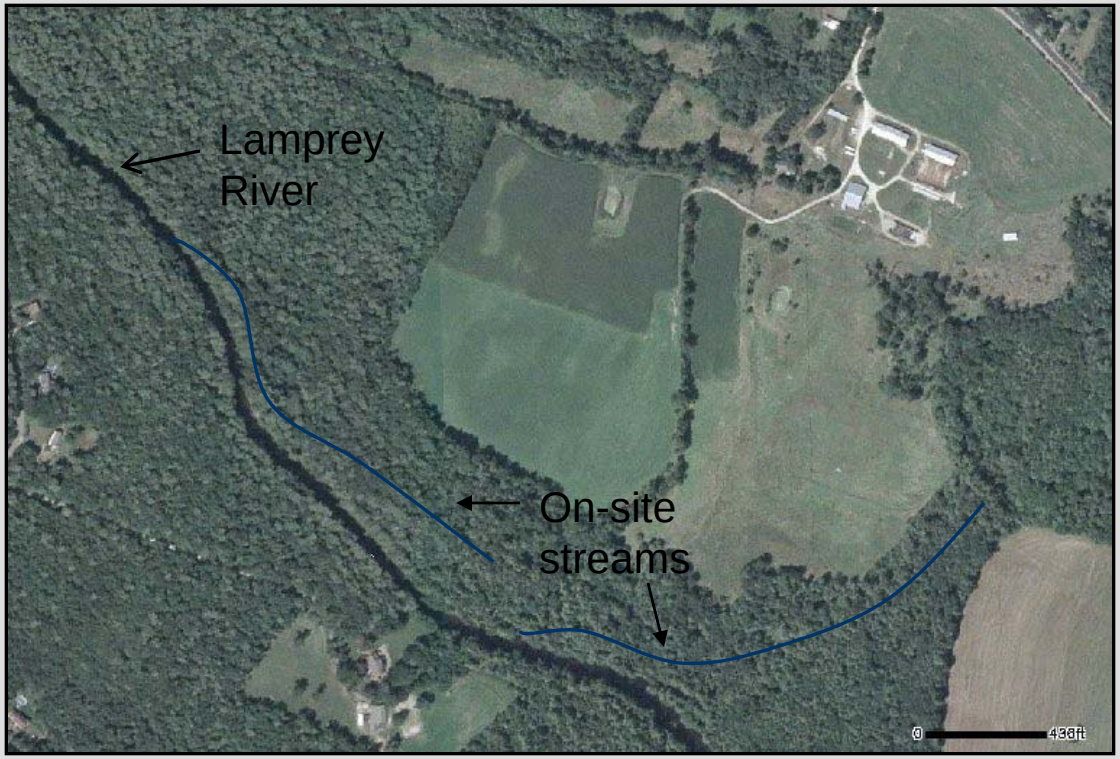
Objectives

1) Determine the minimum river water discharge required to cause flooding of the floodplain and the frequency at which flooding occurs.
2) Examine nutrient (nitrogen and phosphorus) cycling within the stream and floodplain during flooded and dry events and determine whether the floodplain acts a source or sink of nutrients to or from surface waters.
3) Determine whether and how nutrient cycling is affected by the timing (season), duration and spatial extent of inundation.
4) Determine relative influence of denitrification on local nitrogen cycling during flooding events.

Hypotheses

1) The floodplain will flood seasonally (spring and fall) at periods of high water discharge.
2) The floodplain will act as a sink for nitrate.
3) Nutrient concentrations and dynamics in the floodplain will change based on timing, duration and area inundation.
4) Nitrate reduction in the floodplain will occur owing to a combination of water mixing/dilution and denitrification.

Methods: Location



Riparian area adjacent to Burley Demeritt Farm (UNH Organic Dairy)

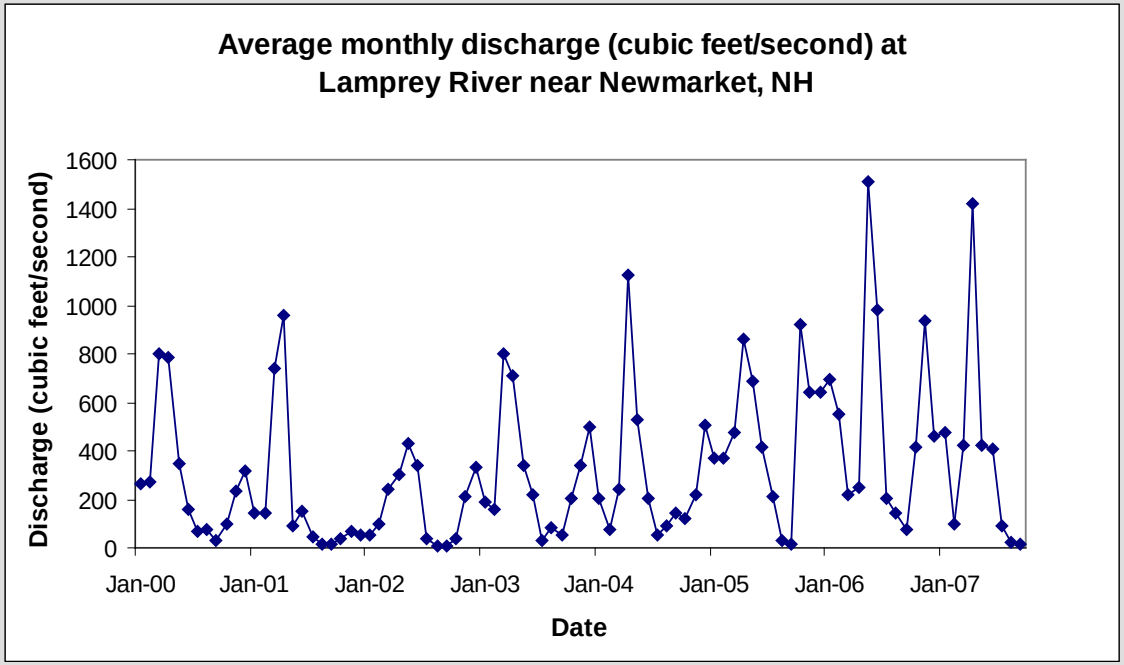
UNH owns ~1.7 miles of undeveloped frontage along the Lamprey River

On-site streams and floodplains are seasonally flooded

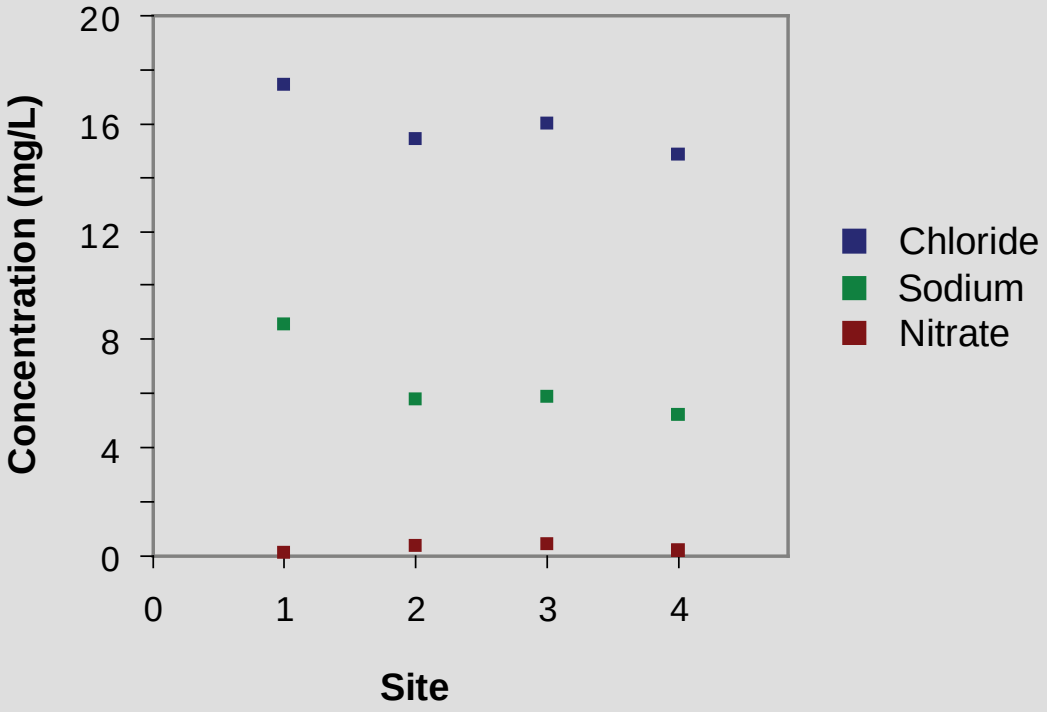
High levels of NO_3 in groundwater (up to 49 mg/L) and stream water (up to 2.9 mg/L)

Methods: Site Description

- Site visits in Fall 2008 show evidence of flooding.
- Stream discharge data for the Lamprey River indicates high discharge in spring (March-May) and fall (November-December)



Preliminary Data



- Nutrient data from creek on 10/28/08. Site 1 is near outlet to Lamprey.
- Cl, Na increase and NO_3 decrease in flooded area (site 1)
- Differences in concentrations of Cl- and Na+ likely reflect mixing and dilution of water masses. Differences in NO_3- may also reflect mixing and dilution, but also uptake and removal via biological productivity.

Methods: Field Sampling

Chemical measurement and analysis

- Bi-weekly sampling for nutrients, DO, specific conductivity and temperature in:
  - streams (every 100m)
  - four sites in the Lamprey River (immediately upstream and downstream of where the streams enter)
- Sampling frequency will increase during inundation and will include the use of an in-field autosampler and in-situ YSI

Site mapping

- Map area of inundation with GPS. Use ArcGIS to determine area of flooding.
- Permanent markers will be installed so that area of inundation can be ground-truthed using geometry

Methods: Field Sampling

Estimation of water discharge

- Stream gauging station has been established in the on-site stream.
- Stream discharge data for the Lamprey River will be obtained from United States Geologic Survey (USGS) stream gauge site near Newmarket, NH (site #01073500).

Tracer/addition experiments

- A combination of conservative tracer (e.g., Cl-) and nitrogen addition experiments will be used to discriminate changes in nitrogen concentrations in floodplain waters resulting from dilution with groundwater and Lamprey River water or from denitrification and biological NO_3- uptake within the floodplain.

Anticipated Results

- *Hypothesis 1: The floodplain will flood seasonally (spring and fall) at periods of high water discharge*.
  - Stream gauging data show that water discharge rate in the Lamprey River is highest in the spring and fall. Inundation of the study site results from overflow of the Lamprey River into tributaries during periods of elevated water level. Accordingly, flooding is expected to occur seasonally during the spring and fall. Field observations in Fall 2008 documented significant flooding of the floodplain and riparian forests in the study site.

- *Hypothesis 2: The floodplain will act as a sink for nitrate*.
  - Many studies have shown that floodplains act as sites of nitrate removal from surface river waters. Preliminary data suggest that nitrate concentrations are lower in floodplain relative to unflooded waters and may reflect uptake of nitrate from surface waters on the floodplain.

Anticipated Results

- *Hypothesis 3: Nutrient concentrations and dynamics in the floodplain will change based on timing, duration and area of inundation.*
  - As the duration and spatial extent of inundation increases so will the potential for uptake of nitrate from surface waters. The timing of inundation is not predicted to change nutrient dynamics unless flooding occurs in the summer and primary biological activity is significantly greater than in the spring or fall.

- *Hypothesis 4: Dissolved nitrate reduction in the floodplain will occur owing to a combination of water mixing/dilution and denitrification.*
  - Preliminary data (Cl-) suggest that mixing of water masses is occurring within the floodplain. Increasing Cl- concentrations within the floodplain are concurrent with decreasing NO3- concentrations - may reflect mixing of higher salinity and lower NO3- Lamprey River water with floodplain surface waters.

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Hydrologic and nutrient dynamics in an unregulated New England floodplain – Take Home Points

- Non-point source pollution from agriculture is a major source of water quality degradation which can lead to eutrophication, anoxia and contamination of drinking water
- Floodplains can act as both sources and sinks of nutrients (through nutrient retention or release).
- Floodplains may act as nitrate removal “hot-spots” due to high levels of denitrification.
- Future research is proposed on an agriculturally influenced Lamprey River floodplain to determine how flooding events impact hydrology and nutrient concentrations