Grand Challenges in Lotic Ecosystem Nutrient Dynamics

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River Network Nutrient Group
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Issues and Context

Transport and processing of nutrients through riverine networks are essential in the biological and chemical linkages between terrestrial and marine habitats as well as the biology of flowing waters. There are several implications of understanding nutrient transport with regard to societal issues. Atmospheric deposition, agricultural management, and point sources of sewage have vastly increased the amount of nitrogen and phosphorus entering many river networks around the world (Vitousek et al. 1997); influences on carbon are not as well documented. Research has demonstrated that rivers and streams are not simply pipes that move nutrients from land to sea but they transform and retain a significant portion of the nutrients that move through them (Alexander et al. 2000, Peterson et al. 2001, Seitzinger et al. 2002). Additionally, hydrologic alterations and anthropogenic impacts on riparian vegetation may influence nutrient dynamics in rivers and streams (e.g., Bernot and Dodds in press).

Processes occurring in the channels of drainage networks alter transport of nutrients, with vast implications for downstream ecosystems. Transport of nutrients to coastal zones is a key environmental issue in the Gulf of Mexico where a hypoxic zone develops annually in response to anthropogenically increased nutrient loading from the Mississippi basin (Rabalais et al. 2001). Such eutrophication is not just limited to the Gulf of Mexico, estuarine and near coastal eutrophication are global environmental problems in all areas with substantial human populations in upstream watersheds (National Research Council 2000).

Nutrient concentrations in rivers channels are also important to lotic eutrophication problems and eutrophication of lakes and reservoirs occurring in the drainage network (Dodds and Welch 2000). Thus, in-channel processing and transport of nutrients are important considerations when determining nutrient criteria, a process currently mandated in the United States.

Finally, rivers and streams are important for carbon transport and may be a substantial source of greenhouse gasses (Seitzinger and Kroeze 1998). Hydrologic alterations, riparian changes, nutrient enrichment, and stoichiometric perturbations all can influence these carbon transport and greenhouse gasses.

Numerous studies on small stream nutrient processing and models and budgets have characterized nutrient transport from large river networks (e.g. Alexander et al. 2002, Caraco et al. 2003), however, the processes that occur in entire river networks are not well characterized. Thus, it may be difficult to predict the outcomes of various management scenarios of nutrient inputs, changes in climate and landuse, and the influence of hydrologic modifications. Here we present our view of the essential questions related to nutrient dynamics in entire fluvial networks, including streams, rivers, and estuaries. While our research focus is on the first set of questions, their relevance lies in the second two major sets of questions.

Recommendations

1. LTER cross site synthesis efforts should include fluvial network nutrient dynamics.
2. All sites should be encouraged to make data readily available on line. LTER sites should participate in ChemDB (with caution, pay close attention to metadata to insure quality).
3. LTER stream sites should interact with coastal and wetland LTER sites to link nutrient cycling studies.
4. There should be several large or medium river LTER sites because this is a missing link in our biogeochemical understanding. These sites should have a river-network approach (e.g. a distributed site).
5. LTER should work with the USGS to obtain access to water-quality and flow monitoring data that complement LTER synthesis efforts (e.g., downstream of LTER sites and in nearby watersheds). This includes seeking USGS assistance in obtaining stream measurement data from the National Water Information System (NWIS)—some key tasks include site identification and advice on appropriate screening and use of the data.
6. LTER stream nutrient researchers should interact with large-scale modelers to extend the scope of LTER results.
7. Cross site efforts of LTER-related research on lotic nutrient dynamics should be integrated with NEON and CUAHSI.
8. LTER should consider LINX and LINXII projects as models for successful cross site research using LTER sites and expanding regionally.

Central Questions

1) What are the controls on mechanisms, rates and processes of nutrient (N, P, C, Si) transformation, storage and export across the fluvial networks (streams, rivers, and estuaries)?
   a) *What controls biotic and hydraulic retention and how much material is stored or permanently removed?*
   b) *How do the elements interact?*
   c) *How does processing change from upstream to downstream?*
      i) How do we link small stream process information to fluvial network properties?
      ii) How important are intermediate-sized rivers to retention?
      iii) Do rates change predictably with river size, and what is the relative effect of rates?
   d) *What are physical, chemical and biological (including anthropogenic) influences?*
      i) At what concentration (or load) will nutrient retention be saturated?
      ii) How has hydrologic modification altered nutrient availability and transport?
      iii) How does metabolic rate influence transport?
      iv) How do lakes and impoundments influence nutrient transformations and transport?
      v) How do controls change spatially, seasonally, and annually?
   e) *Are there long term temporal trends and can we predict nutrient cycling into the future?*
2) What are the ecological implications of nutrient processing within the fluvial network?
   a) *What is the effect of eutrophication on the biology of streams and rivers?*
   b) *How does nutrient processing link to success of invasive species and loss of endangered native species?*
   c) *How do stoichiometric changes alter the biotic community?*
3) What are the effects of various methods of mitigating anthropogenic impacts on fluvial network nutrient cycling?
   a) *What types of restoration are most effective (e.g., dam removal, channel and floodplain restoration, flow manipulation)?*
   b) *What is the dose-response relationship to nutrients?*
   c) *How would tertiary sewage treatment and best management agricultural practices alter current trends in nutrient loading and its downstream propagation?*

Existing Data that Can be used to Characterize Nutrient Dynamics in Fluvial Networks

We have identified several existing sources of data that can be used to approach these questions. Many of the available data sources report only discharge and nutrient concentrations. These data can be useful for calculating nutrient budgets and transport, however, the nutrient process data needed to assess patterns and controls of nutrient processing are rare.

For large rivers the primary long term data have been collected by the USGS. The USGS has good long term coverage for discharge and high quality data for nutrients (good quality control and quality assurance) but discontinuous records across a variable set of stations. Monitoring stations in USGS regional and national biological and water-quality programs (e.g., Heglund et al. 2004, NASQAN II Hooper et al. 1997, NASQAN Alexander et al. 1998, NAWQA USGS 2001) provide some of the most comprehensive long-term datasets for nutrients in large- and mid-sized rivers.

For mid sized rivers the USGS District data provide moderate coverage by state and within individual watersheds for selected years. These data, which are digitally archived in the National Water Information System (NWIS-Web), are collected according to standard quality assurance/control protocols to satisfy the water quality assessment needs of local and State water agencies. Selected state agencies also operate long term monitoring networks, although many to specific problems by placing a large amount of effort into small watersheds for one or a few years.

For small streams the LTER has good data for a number of pristine systems (Table 1), and additional long term chemical data exist from forest service and other study sites. The main problem with these data is access; they are widely distributed and if they are available on the internet they are in variable formats and generally the metadata are poorly documented.

HydroDB is an important project that has created a database with hydrologic data including LTER and USGS sites that will make data available in a common format. Along similar lines, ChemDB is being set up as a data clearinghouse for chemical data and will increase the ability of LTER sites to make cross site syntheses of nutrient dynamics in small streams.

An overarching obstacle to data synthesis is that data collection strategies and storage are not consistent across agencies. Initiatives such as HydroDB and ChemDB will help increase the coordination of small sites. States, USGS, USEPA and the US Army Corps of Engineers are not well coordinated across agencies, although the EPA STORET system allows individuals to search for large amounts of data. Quality control and assurance may be an issue with STORET records. The database created by Alexander et al. (1998) from USGS records of the NASQAN includes historical data from ~1973-95 with good geographical coverage of large rivers across the United States (618 stations). A similar compilation of recent National USGS network and state level stream and river data would be extremely useful. A previous effort (Gosz and Murdoch, 1999) to establish a framework for coordinating national environmental monitoring may serve as a resource for identifying a national set of long-term records of stream nutrients in small watersheds; the authors identified a potential set of nearly 150 university and Federal agency stations for which long-term nitrogen records are available.

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Table 1. Characterization of stream nutrient coverage at LTER sites

Site	Contact	Email	Additional contact	# of locations	General description	Duration	Frequency
Hubbard Brook	**Ian Halm**	ihalm@fs.fed.us	Don Buso	**9**	**headwater tribs**	**63-present**	**monthly**
				15	**synoptic**	**2001-2002**	**monthly**
Niwot Ridge	**Nel Caine**	cainen@spot.colorado.edu	Mark Williams	**10**	**headwater, some may be longitudinal**	**82-present**	**bimonthly**
Andrews	**Sherri Johnson**	johnsons@fsl.orst.edu	Don Henshaw	**8**	**headwater tribs**	**84-present**	**proportional 3 week composites and grab**
				50	**synoptic**	**2001-2003**	**low flow**
Artic	**Adrian Green**	Agreen@mbl.edu		**4**	**2-4th order**	**78-present**	**weekly/monthly in summer**
				48	**synoptic**	**02-present**	**once/summer**
Luquillo	**Bill McDowell**	bill.mcdowell@unh.edu		**8**	**headwater**	**83-present**	**weekly**
Baltimore	**Peter Groffman**	groffmanp@ecostudies.org		**4**	**longitudinal**	**03-present**	**weekly**
				4	**headwater tribs**	**98-02**	**weekly**
Plum Island Ecosystem	**Charles Hopkinson**	chopkins@mbl.edu	Hap Garret	**5**	**inputs**	**93-present**	**monthly**
				30	**synoptic**	**99-00**	**low flow**
Kellogg	**Steve Hamilton**	hamilton@kbs.msu.edu		**20**	**1-3rd order**	**98-present**	**bimonthly**
				200	**synoptic**	**2002-present**	**low flow**
Konza	**Walter Dodds**	wkdodds@ksu.edu		**7**	1-3rd order	**77-present**	**3x/week**
				30	synoptic	**1998-2001**	**summer**

Coweeta	**Jim Vose**	jvose@fs.fed.us		**?**			
Santa Barbara	**John Melack**	melack@lifesci.ucsb.edu		**?**		**02-present**	**storms**
CAP	**Nancy Grimm**	nbgrmm@asu.edu	Nancy Hope	**?**			
Bonanza Ck	**Rob MacLean**		Jock Irons	**4**	**headwater tribs**	**85-87**	**weekly or bimonthly**