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ISSUES – FIGURE SET

Human Alteration of the Global Nitrogen Cycle

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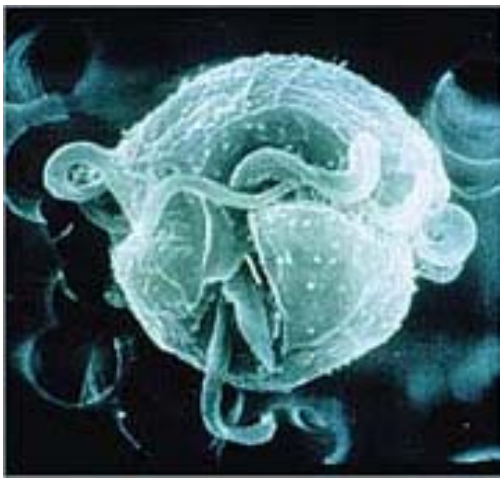

Pfiesteria piscicida
© Howard Glasgow,
JoAnn Burkholder, NCSU

THE ISSUE:
Human activity has greatly changed nitrogen cycling and dynamics worldwide.

ECOLOGICAL CONTENT:
ecosystem, nitrogen cycle, global nitrogen cycling, nutrient loading, nitrogen saturation of forests

STUDENT-ACTIVE APPROACHES:
write before discussion, pairs-share, jigsaw

STUDENT ASSESSMENTS:
replot the data, essay quiz, newspaper article

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OVERVIEW OF THE ECOLOGICAL BACKGROUND

In this **Issue**, students explore large-scale anthropogenic changes to the nitrogen cycle by examining studies that document anthropogenic inputs of nitrogen globally, nitrogen saturation of temperate forests, the export of nitrogen from rivers to the ocean, and the ecology of *Pfiesteria* in the Chesapeake Bay.

Human activity has had a major impact on global nitrogen cycling. Synthetic fixation of nitrogen gas for fertilizer production, fossil fuel burning, and cultivation of leguminous crops has approximately doubled the annual transfer of unavailable N2 to biologically available forms (see first data set). Not surprisingly the impacts of this additional N are great and include higher emissions of nitrous oxide, nitric oxide, and ammonia to the atmosphere, changes to global C cycling, nitrogen saturation in forests, eutrophication of water bodies, and acidification of lakes.

The consequences of some of these alterations to N cycling are already evident. Nitrous oxide in the atmosphere is significantly contributing to global warming. Some forests are beyond the fertilization stage of N additions and are exhibiting the symptoms of N saturation. Nitric acid contributes to acidification in poorly buffered lakes. Outcomes of nutrient loading to fresh and marine waters is arguably the most serious aquatic pollution problem that we have - anoxia and accompanying "fish" kills, tremendous growth of opportunistic species responsive to N and P, and loss of biodiversity have been all too common for decades.

The first data set featured in this Issue document the scale of anthropogenic changes to N cycling globally and is easily accessible to students. The second quantifies how N loadings to watersheds has greatly increased river and marine nutrient concentrations. The third data set focuses on "the cell from hell" and its effects - massive fish kills in the Chesapeake Bay as a result of overflow of hog farm cesspools and blooms of the dinoflagellate *Pfiesteria piscicada*.

The papers also typify ecosystem-scale studies. The perspectives are nitrogen and carbon cycling; partitioning of N into atmospheric, terrestrial, and aquatic fractions; systems analysis; input/output budgets; nutrient limitation; and changes in species composition with nutrient addition (bottom-up controls).

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FIGURE SETS

These are published figures from peer-reviewed research journals and monographs that engage students in data analysis and critical thinking organized by teaching approach, Bloom's Taxonomy cognitive skills, and class size. The student-active approaches listed here are suggestions and examples; modify them as appropriate for your teaching.

These topics are ordered based upon the fate of N as it passes through a forest, rivers, and to the ocean.

Figure Set and Ecological Question	Student-Active Approach	Cognitive Skill	Class Size/Time
(1) How have humans altered the global N cycle? (Vitousek et el. 1997)	write before discussion	comprehension interpretation analysis	small medium / short
(2) What is the evidence for N saturation of temperate forests? (Peterjohn et al. 1999)	support a statement	comprehension interpretation evaluation	small medium / long
(3) How have human activities in watersheds changed N export from rivers? (Vitousek et al. 1997, Howarth et al. 1996)	pairs share	comprehension interpretation analysis synthesis	small medium / short
(4) What is the ecology and biology of *Pfiesteria*? (Burkholder et al. 1992, 1997; Burkholder & Glasgow 2001)	jigsaw	comprehension interpretation application evaluation	small medium / moderate

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RESOURCES

Here are a number of web sites that provide information on the issue of Human Alteration of the Global Nitrogen Cycle:

Pfiesteria

- EPA Pfiesteria fact sheet (www.epa.gov/owow/estuaries/pfiesteria/fact.html)
- NC State Pfiesteria (www.pfiesteria.org); large site includes images and video, background information, nitrogen and oxygen data, real time data, publications, and links
- Univ of NC Pfiesteria site (www.unc.edu/depts/cmse/science/pfiesteria.html); essay titled "The Fuss over Pfiesteria" plus useful links
- Neuse River hotline (www.pamlico-nc.com/health.htm); for the public, includes essay titled "No Hysteria over Pfiesteria", open letter from Burkholder, newspaper article, links
- Univ MD estuary site (www.mdsg.umd.edu/fish-health/); large sets of short essays about fish health and toxic algae, and the Chesapeake Bay
- Harmful Algal Blooms (www.whoi.edu/redtide/); for the public, includes essays about HABs, photos
- Washington Post article (online.sfsu.edu/%7Erone/Environ/Cell%20From%20Hell%20pfiesteria.htm) titled "The Feeding Frenzy of a Morphing 'Cell From Hell'", includes Burkholder quotes
- www.agnr.umd.edu/pfiesteria/agpros.htm; Essay titled "The Agricultural Perspective: Agriculture and Its Relationship to Toxic Dinoflagellates in the Chesapeake Bay", Univ. of MD, Agriculture Dept.

Nitrogen Saturation

- 0verview (www.duke.edu/~mdw7/nitrogen/); excellent site includes figures you can use for class on N saturation; sources of N; microbial, physiological, and community responses; references
- Chronic N Amendment Experiment - Harvard Forest LTER (www.aber.sr.unh.edu/chronicn/hfintro.html); includes photos of plots plus data sets on foliar chemistry; litter, tree, and root biomass; litter decomposition; lysimeter N data, soils; mineralization and nitrification

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Nitrogen Saturation (con.)

- Public Power Institute (www.netl.doe.gov/coalpower/environment/air_q/docs/Saturation.pdf); shows their side of the argument

- EPA: N Saturated Forests in the U.S. (www.epa.gov/airmarkets/cmap/mapgallery/mg_n-satforests.html); US map showing saturated forests

- www.metrocast.net/~dougmac/papers/2003_Bioscience_Aber_et_al.pdf (Aber et al. 2003. Is Nitrogen Deposition Altering the Nitrogen Status of Northeastern Forests? BioScience 53: 375-389)

- Fenn et al. 1998. Nitrogen excess in North American Ecosystems: Predisposing factors, Ecosystem Responses, and Management Practices. Ecological Applications 8: 706-733. (www.sgcp.ncsu.edu/products/pubs/docs/ecolapplications.pdf)

Global Nitrogen Cycle

- World Resources Institute (www.wri.org/wri/wr-98-99/nutrient.htm); for the public title "Nutrient Overload: Unbalancing the Global Nitrogen Cycle" www.esajournals.org/esaonline/?request=get-abstract&issn=1051-0761&volume=7&issue=3&page=737

- *Frontiers in Ecology and the Environment* (Vol. 1(5), 240-246) article by Townsend et al (www.med.harvard.edu/chge/frontiers2003.pdf); titled "Human Health Effects of a Changing Global Nitrogen Cycle", focus includes direct and indirect effects on humans

- ESA Issues in Ecology (www.esa.org/sbi/sbi_issues) includes Issues on Human Alteration of the Global Nitrogen Cycle: Cause and Consequence, Nonpoint Pollution of Surface Water with Phosphorous and Nitrogen, and Nutrient Pollution of Coastal Rivers, Bays, and Seas

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