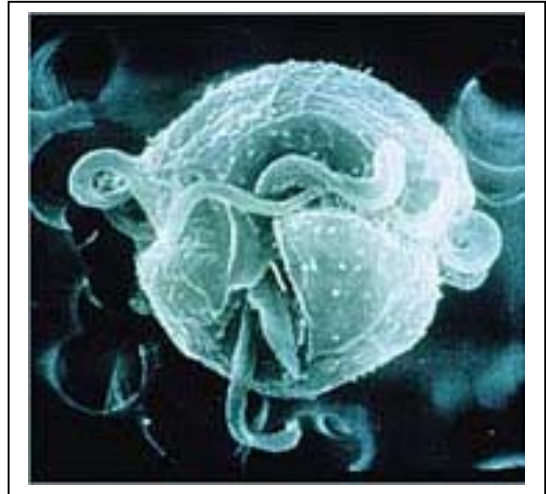


ISSUES – FIGURE SET

Human Alteration of the Global Nitrogen Cycle

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Pfiesteria piscicida
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Figure Set 1: How have humans altered the global Nitrogen cycle?

Purpose: Help students grasp the large-scale anthropogenic changes to global N cycling.

Teaching Approach: "write before discussion"

Cognitive Skills: (see Bloom's Taxonomy) — comprehension, interpretation, analysis

Student Assessment: Replot the data

BACKGROUND

Vitousek et al. (1997 a, b) focus on N in these overview articles because N is a key determinant of species composition and diversity and of the function of all ecosystems. In addition, humans have greatly changed N dynamics worldwide. The abstract lists 8 alterations of the global N cycle as a result of human activity: 1) doubled rate of N input to terrestrial systems with rates still increasing, 2) increased concentrations of nitrous oxide, an important greenhouse gas, 3) losses of soil nutrients (e.g. Ca and K), 4) acidification of water bodies, 5) greatly increased transfer of N to estuaries, 6) increased organic C stored in terrestrial systems, 7) accelerated losses of diversity, and 8) changes in composition and functioning of estuarine and nearshore ecosystems, including contributing to long-term declines in coastal marine fisheries.

Vitousek et al. (1997a, b) published "Human Alteration of the Global Nitrogen Cycle" in Ecological Applications and a second article with the same title as an ESA Issues in Ecology publication. Both are very useful reviews for ecology teaching. For N sources the papers deal with industrial N production for fertilizer, fossil fuel use, addition of N from nitrogen-fixing crops, and biomass burning. Effects on terrestrial ecosystems discussed include nitrogen saturation in forests and effects of N deposition on species diversity. The aquatic section focuses on N in surface and groundwater, acidification of water bodies, and eutrophication. There is also an interesting section about uncertainties such as marine N fixation (uncertain at least by a factor of 10).

According to Vitousek et al. (1997)

"The most fundamental human-caused change to the global N cycle is doubling of the transfer from the vast and unreactive atmospheric pool to the biologically available forms on land (termed "N fixation")... It is fair to conclude that human activity has doubled (or more) the transfer of N from the atmospheric pool to biologically available pools on land. The added N is spread unevenly over Earth's surface - some areas (e.g. northern Europe) are profoundly altered... while others... receive little direct input... but no place on Earth is unaffected."

The increase in N fixed for fertilizer over the last 25 years is clearly shown in Figure 3 in ESA's Issue in Ecology titled "Human Alteration of the Global N Cycle: Causes and Consequences; see Resources below, including a power point show). Here, Vitousek et al. attempt to compare industrial N fertilizer application to deforestation and carbon dioxide releases. The rate of change for anthropogenically fixed N is staggering. The authors point out that use of N for agriculture in developed countries stabilized in the 1970's and that the rapid increases since then is from use in developing countries. They say that more than half of all industrially fixed N for agriculture up to 1990 has been used since 1980.

You can use publication of these articles to stimulate discussion about why leading ecosystem scientists were interested in working together to address this global question - are humans altering the global N cycle - plus the challenges entailed in developing such estimates. For example, each scientists had to look beyond their usual turf (habitats or process) to reach consensus on pathways to focus on. Additional challenges in global budgets include dealing with huge numbers with large uncertainties and incomplete data. The Notes to Faculty section includes ideas for helping students appreciate these kinds of considerations.

Literature Cited

Vitousek, P. M., J. D. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and D. G. Tilman. 1997. Human alteration of the global nitrogen cycle: sources and consequences. *Ecological Applications* 7: 737-750.

Vitousek, P. M., J. D. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and D. G. Tilman. 1997. Human alteration of the global nitrogen cycle: causes and consequences. *Issues in Ecology* 1: 1-15. (available at: www.esa.org/sbi/sbi_issues/issues_pdfs/issue1.pdf)

Additional Resources

- earthtrends.wri.org/text/COA/features/COA_fea_nutovr.htm (World Resources Institute; includes global N sources numbers and figure on fertilizer consumption since 1961)
- cires.colorado.edu/cwessman/4100Fall2003/lectures/TheNitrogenCycle.pdf (Vitousek power point show)
- www.visionlearning.com/library/module_viewer.php?mid=98 (good online review of N cycle for students)

STUDENT INSTRUCTIONS

Write before discussion

Study Figure 1 from a paper called "Human Alteration of the Global Nitrogen Cycle" by Vitousek et al. Follow the step one- step two procedure you have practiced in class.* As you are examining the data write down questions you have, important points in the data, or other topics you would like to bring up in the discussion. The overall question you should address is: why did the scientists who wrote this paper make this particular figure? What central points were they trying to get across? (Note: Tg = teragram or 1,000,000,000,000 grams)

Background

Vitousek et al. published "Human Alteration of the Global Nitrogen Cycle" in a journal called Ecological Applications and a second article with the same title as an Ecological Society of America "Issue in Ecology" publication. Both articles are thorough reviews of this very large topic. In discussing sources of human-made nitrogen (N) the authors deal with industrial N production for fertilizer, fossil fuel use, addition of N from nitrogen-fixing crops, and biomass burning. Effects on terrestrial ecosystems discussed include nitrogen saturation in forests and effects of N deposition (e.g. rain) on species diversity. The aquatic section focuses on N in surface and groundwater, acidification of water bodies, and a phenomenon called eutrophication. There is also an interesting section about uncertainties such as marine N fixation (uncertain at least by a factor of 10).

According to Vitousek et al. (1997)

"The most fundamental human-caused change to the global N cycle is doubling of the transfer from the vast and unreactive atmospheric pool to the biologically available forms on land (termed "N fixation") ... It is fair to conclude that human activity has doubled (or more) the transfer of N from the atmospheric pool to biologically available pools on land. The added N is spread unevenly over Earth's surface - some areas (e.g. northern Europe) are profoundly altered ... while others ... receive little direct input ... but no place on Earth is unaffected."

The data associated with Figure 1 are: 80 Tg/yr (teragram or 10^{12} g) for current industrial fixation of N for fertilizers, >20 Tg/yr released to the atmosphere from burning of fossil fuels, 40 Tg/yr for leguminous crops and forages in agriculture.

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- * In step one you first figure out how the figure or table is set up (e.g. what the labels on the axes mean). You also need to have a pretty good idea of the experimental design - how the scientists set up the experiments - and the hypotheses the scientists address. In step two you can go on to interpreting the

data. For both steps write down any questions you have.

FIGURES

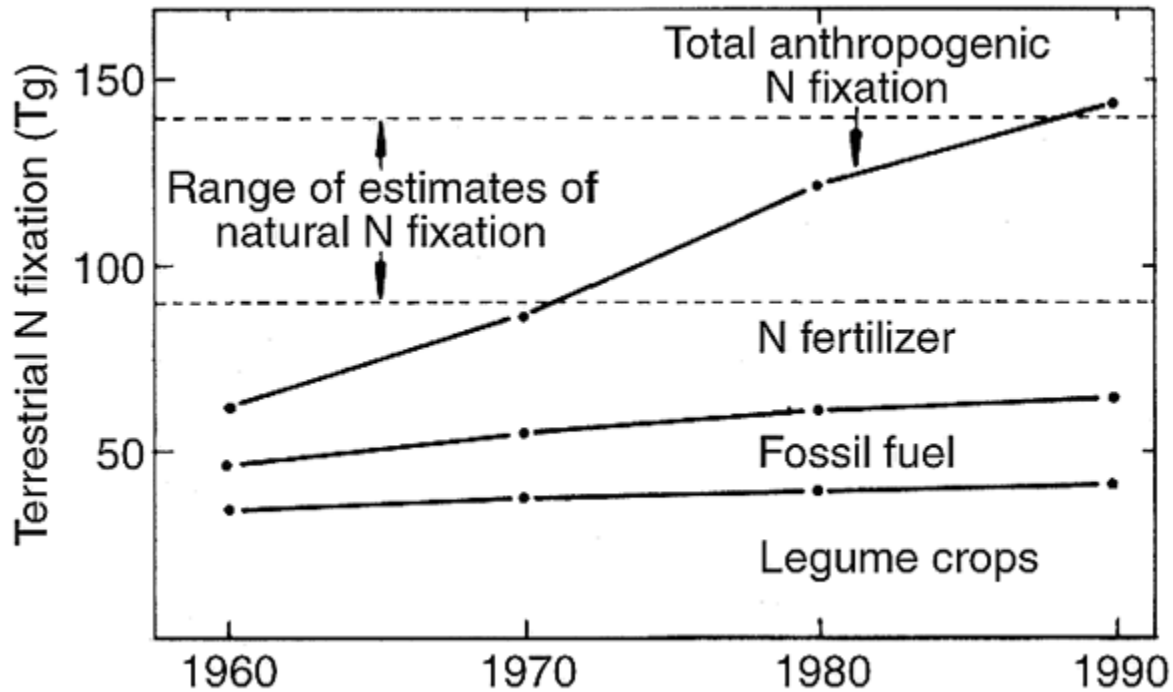


Figure 1. Anthropogenic fixation of N in terrestrial ecosystems over time compared to estimates of natural biological fixation on land. From Vitousek et al. 1997. Human alteration of the global nitrogen cycle: sources and consequences. *Ecological Applications* 7: 737-750, and Vitousek et al. 1997. Human alteration of the global nitrogen cycle: causes and consequences. *Issues in Ecology* 1: 1-15.

FACULTY NOTES

Write before discussion

Scientists are not used to asking their students to write in class, except during an exam. "Write before discussion" is an example of low-stakes writing - when students can write their ideas but not be graded on their work. This exercise gives students time to think and compose their ideas and questions. It is especially useful for students who need "think-time" or who are less confident about interpreting data. We so often forget that students simply need time to ponder questions we pose for discussion. This is particularly true when the questions relate to a data set students must first understand. The time allotted for this exercise depends on the students; an average time is ten minutes.

Humans have changed the global N cycle on a enormous scale, but it is difficult to get this point across to students without quickly losing them in a morass of very large numbers. In addition, it is usually necessary to teach the N cycle so that students understand what nitrogen fixation, denitrification, nitrification, and ammonification all mean. The terms are confusing and the concepts behind them (e.g. anaerobic respiration, chemoautotrophy) are not trivial.

This figure is therefore useful for introducing the massive changes to global N dynamics as a result of agriculture and fossil fuel burning because nitrogen fixation is the only part of the N cycle specifically named.

The data associated with Figure 1 are: 80 Tg/yr (teragram = 1,000,000,000,000 g) for current industrial fixation of N for fertilizers, >20 Tg/yr released to the atmosphere from burning of fossil fuels, 40 Tg/yr for leguminous crops and forages in agriculture.

A challenge in using this figure will be to help students appreciate why these huge increases in N by human activity is such a concern. One way to approach this would be to choose an effect that most interests you (e.g. the various effects on atmosphere or terrestrial and aquatic systems) and bring the point home with some detailed descriptions. For instance, as a marine ecologist I would describe effects of N loading to estuaries such as the Chesapeake Bay or Long Island Sound, including anoxia and fish kill events. You might focus on local concerns (sewage treatment plants, agriculture, acid rain) as well.

Some students will have a difficult time understanding the figure as presented because they are not used to seeing data shown in this way (stacked values). Students will understand these data much better if they rework them to create a new figure, as suggested below for an assessment. This could be done as homework or in class with students working together in small groups. They can estimate the values from Figure 1 and decide on a different way to present the data (groups can present their different approaches in small classes), or you can suggest a few approaches (e.g. stacked histograms, pie graph). This will also give students experience creating their own figures with data. These figures need not be "beautiful" Excel figures; actually sketching them by hand allows many students to engage with the data better.

Questions for Discussion:

- In Figure 1, the range for estimates of natural N fixation is about 100-about 140 Tg. Why is the range so large? How might scientists come up with these values?
- Where do the numbers in the Figure come from? How accurate do you think these numbers are - how might you know this? What do you suppose limits scientists' ability to more accurately define these numbers?
- Why is there N in fossil fuels? What is its source?
- According to Vitousek et al. use of N for agriculture in developing countries stabilized in the 1970"s and the rapid increases since then is from use in developing countries. Explain this statement and its implications in regard to regulation of global N pollution.
- They also say that more than half of all industrially fixed N for agriculture up to 1990 has been used since 1980. Explain this statement and its implications.

Student Assessment: Replot the data.

For some people the data in Figure 1 are graphed in a way that is difficult to understand. For homework replot the data in this figure and be prepared to present your new figure in class (use the overhead transparency or other means described by your professor). You can either make the new graph by hand by simply sketching it on a piece of paper; alternatively you can use Excel to make a more "official" looking figure. Beauty of the new graph is not important, but clarity is.

Evaluating an Issue: How do you know whether it is working?

On-going (also called formative) evaluation of the approaches you are using is critical to the success of student-active teaching. Why try out new ideas if you don't know whether or not they are working? This is a brief overview of formative evaluation. For more information, go to the Formative Evaluation essay in the Teaching Section.

Course Goals:

Formative evaluation only works if you have clearly described your course goals - because the purpose of the evaluation is to assess whether a particular technique is helping students reach these goals. For instance, most of us have "learn important ecological concepts and information" as a course goal. If I reviewed the nitrogen cycle in a class, for evaluation I might ask students to sketch out a nitrogen cycle for a particular habitat or system. Each student could work alone in class. Alternatively, I might ask students to work in groups of 3 and give each group a different situation (e.g. a pond receiving nitrate from septic systems, an organic agricultural field, an agricultural field receiving synthetic fertilizer). The students could draw their flows on a large sheet of paper (or an overhead transparency) and present this to the rest of the class.

The Minute Paper:

Minute papers are very useful evaluative tools. If done well they give you good feedback quickly. Minute papers are done at the end of a class. The students are asked to respond anonymously to a short question that you ask. They take a minute or so to write their response in a 3x5 card or a piece of paper. You collect these and learn from common themes. In the next class it is important that you refer to one or two of these points so that students recognize that their input matters to you. The [UW - FLAG site \(www.wcer.wisc.edu/nise/cl1/flag/\)](http://www.wcer.wisc.edu/nise/cl1/flag/) gives a good deal of information about using minute papers including their limitations, how to phrase your question, step-by-step instructions, modifications, and the theory and research behind their use.