Confronting the 'third level of ignorance': How we teach about the natural world

Tom Lee

Department of Natural Resources and the Environment
College of Life Sciences and Agriculture

2009-2010 Brierley Presentation
March 9, 2010

Introduction

A little over a year ago, a group of UNH scientists wrote to the local press, expressing their concern about the ecological state of New Hampshire's largest and most important estuary, Great Bay. [IMAGE] Last fall, the Piscataqua Region Estuaries Partnership confirmed that Great Bay is close to the tipping point, with high levels of dissolved nitrogen derived from human sources in the Great Bay watershed. The estuary is indeed changing, with declining water clarity and loss of eelgrass beds already evident. The Great Bay story epitomizes so many of our environmental problems, which are typically well-developed and already difficult to solve by the time the public and decision makers become aware of them. Great Bay is a regional issue, but most of our global environmental problems have shown the same pattern, with belated recognition by those with the power to solve them. This is true for global climate change, and certainly true for the human-driven loss of biological diversity. The loss of species and genes is a quiet and complex issue to which most people are simply oblivious.

In fact it seems to be generally true that when it comes to environmental issues, most folks exemplify what Phillip Armour has called the "third level of ignorance". According to Armour, there are five levels of ignorance; I'll just give you three:

> First level: We do not know the solution.
> Second level: We do not know the problem.
> Third level: We do not know that there are problems.

When it comes to human interactions with the natural world, it seems that many people, including many of our leaders, might be described as "ignorant at level 3". To be fair, there are individuals who predicted the environmental problems we face today including global warming and the situation at Great Bay-- but their warnings went largely unheeded. Now it's true that we've gotten a little better at reacting to bad news. When New Hampshire's Department of Environmental Services got the word about Great Bay they took immediate action, charging coastal towns with developing a plan to deal with nitrogen. But we'd be a lot better off if we had anticipated these problems and been proactive about them.

Why aren't we more proactive? There are surely many reasons and I won't make a comprehensive list of them here today. But I do think that one reason is that our citizenry and leadership are not at all well educated in the natural sciences, and are largely unaware of the natural processes that sustain them.

Objective and caveats

Consequently, I'd like to talk briefly on how we teach about the natural world at the university level. In order for individuals and communities to make more informed decisions about environmental issues, I believe more students need exposure to the natural sciences, and more importantly, I think we need to broaden our approach to teaching about the natural world even at the introductory levels.
A couple of caveats:

First, when I use the term "the natural world", I'm talking about chemical, physical, and biological processes that can proceed without assistance from people. Of course, the natural world includes the cosmos and astros, but today I'll limit my remarks to natural systems within or near Earth's biosphere.

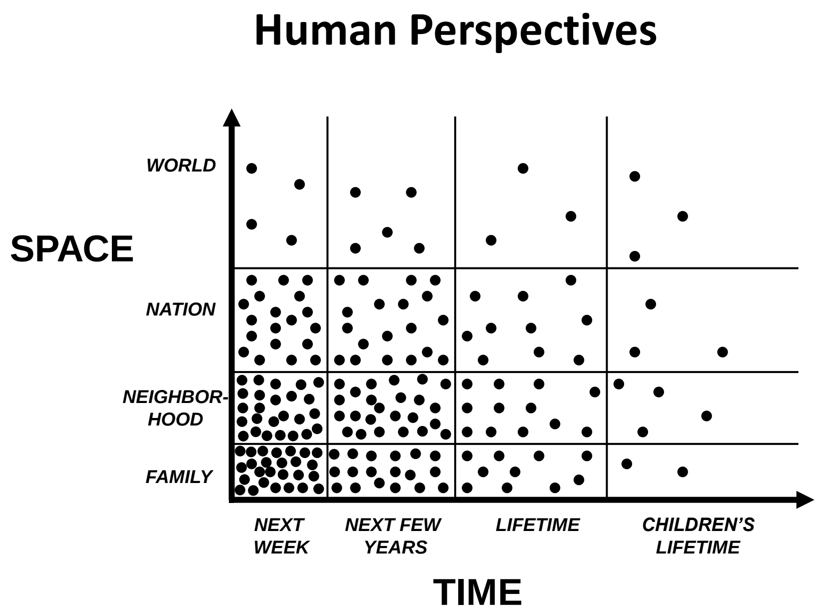
The second caveat is that none of the ideas I'll present here are original with me. In fact, I'm not a very creative thinker. I'm a good thief, however, and all the ideas I'll present to you today, were shamelessly stolen from others. I do want to note here that the University of New Hampshire has received accolades for its commitment to environmental sustainability, and rightly so. The university's sustainability efforts are summarized in the recently published book, "The Sustainable Learning Community", which includes a very fine section, edited by John Carroll, on "teaching and learning sustainability". The essays in this section have stimulated my thinking in preparing my remarks for today.

Defining the problem more precisely

As I said earlier, I believe that at least part of our inability to anticipate and defuse environmental problems is that, while each one of us is physically dependent on the natural processes around us, most don't give much time or thought to these critical dependencies. Why not?

One reason has to do with scale at which we live our lives. Humans live their lives at scales of space and time that are different from those at which important natural processes operate.

As individuals, most of our thoughts and actions relate to immediate needs on very local spatial scales. My personal initiation to this concept was a graph in the first edition of the *Limits to Growth* (Meadows et al. 1972).



After Meadows et al. 1972. The limits to growth. Universe Books.

The horizontal variable here is time scale, from next week on the left to your children's lifetime on the right. The vertical axis is spatial scale, from family and neighborhood at the bottom to the globe at the top. Each dot indicates a human concern located based on scale in time and space. Most of the dots lie in the lower left, with short-term family and neighborhood issues. For example, at this moment, while listening to me speak, you may also be thinking: "This week I've got to find someone to repair the roof", or "I've got to get that grant proposal done by Tuesday". Most of our lives are spent on these sorts of issues with relatively little time spent thinking about the issues that will confront us a few decades down the line. As Lester Brown has noted, despite its many desirable qualities, even our market economy "favors the near term over the long term, showing little concern for future generations."

While *we* focus on the near term, some of our *impacts* on natural processes may take decades or centuries to become apparent. One example is *extinction debt*. Rates of species extinction due to human activity are already high, but much recent evidence suggests that there are huge lag times in the extinction process and that habitat loss today has created an extinction debt that will be paid out gradually over the coming decades and even centuries. Thus, the payback for habitat loss may be many years away, hence it is largely ignored.

The second reason that we have a difficult time anticipating environmental problems is that most people are not "systems thinkers". The scientific tradition that most of us in my generation were raised on is the scientific reductionism that goes back to Descartes. And certainly we've come a long way with reductionist thinking. But many natural systems and of course human interactions with natural systems are perhaps best analyzed through something called a systems approach. Systems thinking is the process of understanding how parts of a system influence each other within the whole. It is, for example, the perspective that allows us the see Great Bay as an ecological system, a system that includes all of its freshwater tributaries and all of the inputs that people deposit into them [IMAGE].

Systems thinking caught hold back in the 1960's with the emergence of computers and the potential for making models of complex systems. Since that time, systems thinking has had a profound influence on scholars in ecology, engineering, computing, business and many other fields. But I'm not sure how far the concept has spread from academia. To give a specific example, a lot of the people I've talked with about the nitrogen problem in Great Bay, including some with a science background, were surprised to learn that the problem originated not with Great Bay itself, but with human deposition many miles away. Despite the fact that most people seem to know the definition of "ecosystem", I'm not sure that systems thinking has accompanied the definition.

A third reason for our inability to anticipate environmental problems is that many of us have little direct contact with the natural world. Here in the United States, most folks live and work in climate-controlled buildings. Our electronic media provide us with diverse and endless indoor entertainment. Our technology, wonderful as it may be, has insularized us. I think Daniel Schorr had a point when he said "the first victim of technology is reality". The lack of outdoor experience for children has been lamented in Richard Louv's insightful book *Last Child in the Woods*. Louv argues that children deprived of interaction with nature suffer "nature deficit disorder".

Our academic programs are focused indoors as well. The academic schedule is keyed to relatively short class meetings during a well-defined academic day. These constraints even limit what traditionally outdoor-oriented programs can do. For example, there are universities where you can take a course in ornithology (study of birds), without seeing a live bird. But even here at UNH, trips that last more than half a day often run into conflicts with other courses. There is generally very little flexibility in accommodating these sorts of experiences, even when they are of great value. And then there's the issue of arranging transportation which, in recent years here at UNH has become much more difficult. So there are real barriers to getting students outside.

A fourth reason for our inability to anticipate environmental problems is that most people know relatively little natural history. *Natural history* has been defined by one source as "the systematic study of any class of natural objects or organisms". Doesn't sound too appealing, does it? The term has become an anachronism and is regarded, even by many scientists, as passé. But the demise of natural history means that most people have little knowledge of local geology, floras, and faunas and little understanding of relationships between organisms and their physical surroundings. If one has little or no understanding of the diversity of life in one's own backyard, how can that person comprehend the consequences of local or global extinction of life? The lack of knowledge about natural history is not universal; a Finnish acquaintance of mine once told me most of the folks in his home town knew all the plants – even the mosses – that grew locally. That's not typical in most American communities.

A final issue is that most of our citizens have a relatively weak understanding of science as a process. Traditionally science is a taught as a set of established generalizations or truths. Most people understand the *results* of science, the principles that science generates, but they don't know much about science as a process. Students don't always get a chance to experience the scientific process, collecting their own data, analyzing it, interpreting it, and making inferences. They don't get much experience evaluating or discussing scientific evidence. For example, most folks don't know the difference between scientific inferences made by correlation versus those made by manipulative experiments. Because most folks think science is just a list of facts, they have difficulty in coming to grips with scientific uncertainty and scientific debate.

So, is there a solution?

How do we develop in our students a better understanding of natural processes and human interactions with them? Can we at least upgrade ourselves to that second level of ignorance?

First, the scale issue. How do we get students to think about natural processes at more extensive spatial and temporal scales?

One can get students to think about longer *time scales* by having them predict the far future. Stated so simply, this sounds like it might be a wildly speculative, error-prone and even goofy activity, but it *is* possible for undergraduate students to make quantitative predictions about future states of natural systems using modeling.

Now simulation models used to be the purview of folks with advanced training in math and programming, but it is a fact that you can make fairly realistic and accurate models using readily available software, even spreadsheet software.

For example, students in the Earth Systems Science course taught by George Hurtt and Cameron Wake, build a model that predicts the future temperature of the earth, over decades and even centuries. To build such a model requires them to first understand a variety of subsystems that contribute to earth's temperature, including the atmosphere, the oceans, and of course human contributions. The model can be run with or without human-produced greenhouse gases. [IMAGE] Here's one such model, produced by a team of students Becca Lehr and Jordan Goodrich, with earth's temperature indicated as the stock in the middle and all the contributing variables nearby. These two very creative students built a more sophisticated version of the model that actually estimated the effects of human-caused carbon emissions on the onset of the next glacial period, several millenia away, showing that these emissions may be sufficient to delay the onset of the next glacial cycle. [IMAGE] Now the time scale of many centuries may be difficult to grasp, but the point is simple, students can learn about long term changes in complex systems using modeling.

Model building not only allows students to examine phenomena over broader time scales, but it requires that they develop ***systems thinking skills*** as well. Students are introduced to the concepts of time lags and positive and negative feedbacks, which are at the root of many of our environmental problems.

An issue related to time scale is the notion of "shifting baselines". To assess human impact, we often like to establish the baseline or reference state of a natural system; the so-called pristine condition. But human impact sometimes causes natural systems to change so rapidly that what is seen as the "normal" state today is quite different from the normal state a decade or two ago. Walk into a white or red pine forest in the New Hampshire seacoast today and you're likely to see an understory of a tall shrub, called glossy buckthorn. The tall, large pines and the thick, woody understory form a community that seems natural and that you might imagine was a common sight in the seacoast region for centuries in the past. But in fact, buckthorn is a non-native, invasive species that was rare in our area 50 years ago. In one of my classes I ask the students to reconstruct the invasion of a pine forest by buckthorn. Using wood ring analysis they can age a random sample of buckthorn and project the buckthorn population back in time. They conclude that 40 years ago buckthorn was absent from the forest and the forest's understory structure was entirely different than it is today. Looking back in time can be just as informative as projecting forward and helps us assess anthropogenic change and to detect shifting baselines.

The approaches I've described to address time scale don't necessarily require a lot of specialized training. You can make models and measure tree rings with first-year students. Getting students to broaden their spatial perspective is a bit more challenging because students may have to learn some specialized skills. The major tool for expanding one's spatial scale of course is Geographic Information Systems or GIS. GIS allows us to take remotely sensed images of the earth and superimpose layers of spatial information, both natural and human-based. [IMAGE] In the image shown here, provided by Russ Congalton, a digital image of Durham taken from a satellite is shown as the lowest of a set of layers. The other layers or themes include contour lines, land cover, utilities, and buildings. Students can use GIS to examine relationships between different themes, over a wide range of spatial scales. Right now, use of these tools requires specialized training and today is limited to advanced courses, but if you've played with Google Earth lately, you may get the feeling that widespread use of GIS is just around the corner.

Let's leave the issues of scale and systems thinking and move on to the question of getting outside. If you want students to learn about natural systems, it's best that they experience those systems first-hand in the out-of-doors.

We're so fortunate here at UNH to have a variety of landscapes including some undeveloped land within a short distance of campus. Very few universities have anything like our College Woods, Foss Farm, or Woodman Farm so close to campus. Many of our faculty make use of these outdoor classrooms, but more of us could do so.

For 10 years I had the pleasure of co-teaching General Ecology with Jim Taylor. In fact, I learned more about teaching from Jim Taylor than from any other single person. In getting General Ecology up and running, Jim and I had to come up with lab projects. Jim did the lion's share of the work on this, and one day he announced to me that one of our projects would be live-trapping of white-footed mice in the woods at East Foss Farm. I thought he was joking. To do a trapping project with 100 students seemed impossible. But Jim had it figured out. We ran the trap grid for two weeks. A group of 10 or so students would go out twice a day, once at 6 p.m. to set the traps, once at 6 am to check them. Each student went out just twice, once in the morning, once at night. On the morning excursions they got to see live white-footed mice up close, [IMAGE] and if they wished they could handle them. Although the focus of the project was the white-footed mouse, on most days our traps picked up the odd red-backed vole, various shrew species, a jumping mouse, or a southern flying squirrel. We frequently caught flying squirrels, which, when released, would usually scamper up the nearest tree, and then glide – fly – to the NEXT tree, a sight that no one who has seen it will ever forget.

What did the students get from this experience? They learned some important ecological techniques, live-trapping and mark-recapture, but I think they also learned something far more important than these. They saw an animal community – a guild of nocturnal small mammals – that most of them hadn't even known existed. Walk through the woods during the day and you don't see or hear these creatures. One might say, "so what, of what importance are these animals?" Well, these animals are seed eaters; they eat tree seeds, and the large quantity of seeds they consume likely influences the tree species composition of the forest. They're also prey for a variety of carnivores, including owls and weasels. For these students the forest ecosystem just got a little more complex and a whole lot more real.

Not all field experiences are quite so compelling as mouse trapping, but in terms of student understanding and retention, two hours in College Woods is often worth more than a couple of weeks of lecture, at least for some topics. Students will confirm this.

Related to getting students outside is the issue of resurrecting natural history. I think it's to resurrect natural history as a legitimate academic subject. It's true that, to understand the natural world, students *do* need to know a few organisms and a few body parts, but naming things can't be the end of it. The emphasis should probably on the processes and interactions involving these organisms. Jim Haney and Al Baker have for many, many years taught a field course in lake ecology that really seemed to meet the goal of looking at processes in natural systems, processes that relate the biotic and abiotic worlds.

Inspired by Haney and Baker, a few years ago I developed and taught a field course about New Hampshire's forests. We have about 80 different kinds of forest in the state, from pine-oak woods here in the southeast to spruce-fir forests up north, and these natural communities are an integral part of the state's economics, aesthetics, and way of life. The goal of the course was to get students to walk into any forest and, using their powers of observation and deductive reasoning, reconstruct the history of the forest, explain how climate, soils, and disturbance determined its tree composition, and then, most importantly, predict future changes in composition and structure, including changes caused by human impact. As it turns out you can resolve these tasks knowing a relatively small and palatable number of plant species, and understanding a relatively small number of processes and interactions.

Based on what I'd heard about similar field courses I expected that the approach would be successful. But the results greatly exceeded my expectations. The students took to the course format like ducks to water. Learning the tree names, soil properties, and ecological principles became the means to an end, which was *predicting* the future of our forests. My guess is that these students learned enough natural history so that they *could* understand and evaluate the impact of some local development on forests in their own communities, or, scaling up, evaluate the significance of global losses in the biological diversity of forests.

***Learning the process of science*.** Lastly, it's also important for students of the natural world to understand the process of doing science. And the best way to do this is to experience the process first hand. The notion of teaching through "inquiry" has been around a long time and it works particularly well in the sciences. The idea is to have students ask questions and develop hypotheses about a system, then have them come up with study design and methodology. Data are collected, analyzed and interpreted. My colleague, Serita Frey, has used an inquiry approach in her introductory soils course. Last year's class asked the question: how do different land use practices affect soil properties? [IMAGE] Once again, UNH-owned land served as the field laboratory, as the class chose to compare soils on lands used for pasture, cultivation, or forest. Based on soil science principles they'd learned in class, the students made specific, testable, predictions about how these soils would differ, then designed a set of observations to test their predictions. The observations involved a healthy mix of both field and lab work and the students analyzed their quantitative data with statistics. One of the student's predictions was that soil organic matter would be lowest in cultivated soil, and that prediction was indeed borne out by the data. [IMAGE] The students discussed and interpreted their data based on what is known about patterns of soil OM, and put together a presentation for the UNH farm manager. Serita is now developing a studio soils course that will be largely inquiry based.

By the way, I think our university is to be lauded for including the inquiry concept in its Discovery program, and to expect undergraduates to take at least some inquiry-attribute courses. It's important to keep in mind however that, in the sciences, introductory courses that are purely inquiry-based will be difficult to teach. Students often need a foundation of information to use as a basis for developing good, testable questions, and that will require some traditional methods.

Conclusion

I suspect that I've been preaching to the converted here today. I expect that many of you would agree that the issues of temporal and spatial scale, systems thinking, natural history education, field work, and inquiry based learning are all worthwhile. In fact, the examples I've covered have shown that a lot of these issues are being addressed in our more advanced courses. I think, however, that we need to make sure that some of the approaches we've discussed today are used in our introductory courses where they will reach a greater number of students. I'm not sure how to go about this, but just as a random example I could envision an introductory level biology course including a lab where students modeled the process of extinction and estimated extinction debt.

Now, I'm not under any illusions about the value of the approaches I've reviewed in this presentation. Moving away from the *"third level"* of ignorance", getting people to *anticipate* the responses of the natural world to human impacts, will take more than just a different approach to teaching the natural sciences at universities.

Other academic disciplines must adapt as well. And this is happening. In the social sciences, including economics, the acknowledgement and inclusion in courses of what were once called "economic externalities", for example loss of natural capital and the costs of pollution effects, reflects a broadening of both temporal and spatial perspectives in those disciplines. The attempt by social scientists to quantify the value of what are called 'ecosystem services' and to bring this concept into the classroom, is another example of this sort of thinking.

But I'm fairly certain that a better understanding of natural processes and how they respond to human impact is a key element. By broadening the spatial and temporal scales we use in our courses, by using a systems approach, by giving our students more in-the-field experience, by cultivating their knowledge of natural history, and by asking them to engage in the scientific process we may one day elevate ourselves to the second level of ignorance. And wouldn't that be nice?