Preparing for the future: teaching scenario planning at the graduate level

Reinette Biggs[1*], Matthew W Diebel[1], David Gilroy[1], Amy M Kamarainen[1], Matthew S Kornis[1], Nicholas D Preston[1], Jennifer E Schmitz[1], Christopher K Uejio[2], Matthew C Van De Bogert[1], Brian C Weidel[1], Paul C West[2,3], David PM Zaks[2], and Stephen R Carpenter[1]

Are environmental science students developing the mindsets and obtaining the tools needed to help address the considerable challenges posed by the 21st century? Today's major environmental issues are characterized by high-stakes decisions and high levels of uncertainty. Although traditional scientific approaches are valuable, contemporary environmental issues also require new tools and new ways of thinking. We provide an example of how such new, or "post-normal", approaches have been taught at the graduate level, through practical application of scenario planning. Surveyed students reported that they found the scenario planning course highly stimulating, thought-provoking, and inspiring. Key learning points included recognizing the need for multiple points of view when considering complex environmental issues, and better appreciating the pervasiveness of uncertainty. Collaborating with non-academic stakeholders was also particularly helpful. Most students left the course feeling more positive about the potential contribution they can make in addressing the environmental challenges that society faces.

Front Ecol Environ **2010; 8(5): 267–273, doi:10.1890/080075 (published online 22 May 2009)**

Wealth, technology, and fast-growing human populations are placing unprecedented pressures on the planet (Steffen *et al.* 2004; MA 2005c; IPCC 2007). Are tomorrow's environmental scientists being appropriately prepared to help address the challenges we face? Future environmental research will focus largely on established issues, such as climate change and biodiversity loss. However, the context for this work is likely to differ from that in which science has traditionally been conducted and is still predominantly taught (Funtowicz and Ravetz 1993; Gibbons *et al.* 1994; Ziman 2000). Environmental issues are becoming ever more politicized because of their increasing impacts on society. Consequently, the ways in which environmental problems are defined, the methods used to study them, and the interpretation of results are increasingly being scrutinized and contested. Such scrutiny also highlights the extent to which many scientific endeavors are underpinned by values and assumptions that may favor certain sectors of society above others (Bocking 2004; Sarewitz 2004).

It is also becoming apparent that most environmental issues are characterized by substantial and often irreducible uncertainties (eg Pilkey and Pilkey-Jarvis 2007). This is due to the complex nature of environmental systems: they involve many interdependent components that span multiple spatial and temporal scales and are self-organizing and constantly evolving (Holling 2001; Manson 2001). These characteristics create inherent limitations for the predictability of complex systems. For example, despite substantial investment in research and tremendous growth in computing power, uncertainties in future climate change projections have not lessened appreciably over the past 30 years (Roe and Baker 2007). Such intrinsic uncertainties are being exacerbated by rapid and novel changes in drivers of environmental change, such as population growth and new technologies.

High-stakes decisions and high levels of uncertainty set the stage for what has been termed "post-normal science" (Funtowicz and Ravetz 1993; Figure 1). Post-normal science involves a reframing of the relationship between science and decision making. The belief that scientists can provide certain, objective information on which to base policy is increasingly recognized as inappropriate when confronting contemporary environmental problems (Bocking 2004; Sarewitz 2004). In post-normal contexts, far-reaching societal decisions have to be made, often with considerable urgency, on the basis of information

In a nutshell:

- Many pressing environmental issues require skills and approaches to problem-solving not traditionally taught at universities; these include acknowledging diverse values and worldviews, dealing with high levels of uncertainty, and working in collaborative, interdisciplinary teams
- Scenario planning provides a tool for teaching such skills at the graduate level, as a complement to traditional scientific training
- Environmental science students found exposure to these approaches stimulating, refreshing, and inspiring

[1]*Center for Limnology, University of Wisconsin, Madison, WI* [*]*(oonsie.biggs@stockholmresilience.su.se);* [2]*Center for Sustainability and the Global Environment, University of Wisconsin, Madison, WI;* [3]*The Nature Conservancy, Madison, WI*

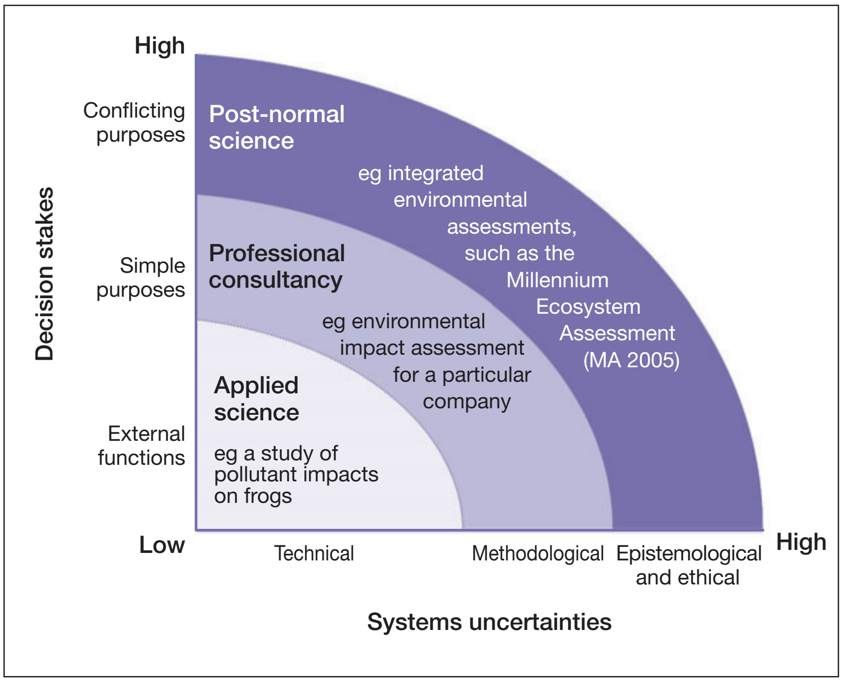


Figure 1. *Today's major environmental issues are characterized by the conditions of post-normal science: uncertain facts, disputed values, high stakes, and urgent decisions. These conditions do not change the routine practice of traditional applied sciences and professional consultancy, but reframe the context in which they are carried out. Research problems become set and the solutions are evaluated by a broader community of stakeholders. Figure adapted from Funtowicz and Ravetz (1993).*

that is riddled with uncertainties. In addition, facts and values often cannot be clearly separated. It is increasingly argued that the most effective approach under these conditions is a dialogue between all parties, where scientists, as well as other stakeholders, take their places at the table. To ensure high-quality decisions, the decision-making process itself and assessments of information quality become critical (Funtowicz and Ravetz 1993; Gibbons *et al.* 1994).

Post-normal science draws on traditional scientific tools but also requires the development of new tools and, in particular, different ways of thinking (Bammer 2005; Norgaard and Baer 2005). A popular tool used in post-normal scientific contexts is scenario planning (van der Heijden 1996; Peterson *et al.* 2003). Well-known examples of post-normal scientific processes that include such planning are the Millennium Ecosystem Assessment (MA 2005c) and the Intergovernmental Panel on Climate Change Assessment (IPCC 2007). In post-normal science, the aim is not primarily to reduce or eliminate uncertainty, but to identify and manage it. Differing values are made explicit and become part of the deliberations. The process is characterized by interactive dialogue between large, interdisciplinary groups of scientists and other stakeholders, and the potential contribution of non-scientific knowledge is recognized. The outcomes of the process are evaluated by an extended peer community, which includes scientists as well as government officials, business representatives, and members of the public (Funtowicz and Ravetz 1993; Gibbons *et al.* 1994).

Despite the growing importance of these emerging tools and mindsets, graduate students – particularly in the natural sciences – typically receive little exposure to these approaches. As with traditional research skills, post-normal scientific skills are best acquired through practical application. The aim of this paper is to provide an example of how post-normal scientific thinking might be taught at the graduate level using scenario planning. We emphasize that post-normal science does not replace the need for traditional scientific skills, but provides an important expansion of students' skill sets. Our ideas stem from a seminar, held at the University of Wisconsin–Madison, during which we worked with local community members to develop scenarios for the future of Lake Wingra in Madison, Wisconsin. The authors of this paper are the students and the instructor of that class. To qualify for authorship, students had to provide detailed written reflections on the course, draft a section of the paper, and review a full draft of the manuscript.

Scenario planning

Scenario planning is a highly creative exercise that is particularly well-suited to considering complex systems, fundamental uncertainties, and conflicting values (van der Heijden 1996; Kahane 2004). Scenario planning has been applied in a wide range of contexts, including political decision making, business planning, and environmental management. The outcome of a scenario-planning process is typically a set of three to five scenarios, or plausible stories about how the future might unfold. Depending on the available resources and the objectives of the process, these qualitative storylines may subsequently be quantified by means of, for instance, integrated assessment models. Scenarios often describe unlikely or surprising futures. The intention is to provoke consideration of how critical uncertainties may affect the future, and thereby broaden perspectives, challenge assumptions, and highlight hidden dangers and opportunities. Scenario planning differs from other approaches to future assessment, such as forecasting and risk assessment, in that it explicitly considers a range of possible futures, rather than focusing on the accurate prediction of a single outcome (van der Heijden 1996; Peterson *et al.* 2003).

The scenario-planning process is typically conducted through a series of workshops involving scientists, managers, and stakeholders such as non-governmental agencies, community groups, and members of the general public. Although not always reached, the shared understanding that these workshops can foster is often one of the most valuable outcomes of the process, and may, in itself, be a reason for conducting scenario-based exercises (Evans *et al.* 2006; Zurek *et al.* 2008). Scenario planning can be applied at a wide range of scales. For instance, the Millennium Ecosystem Assessment (www.MAweb.org) developed scenarios at the global level (MA 2005b), as well as at regional and local levels (MA 2005a).

The scenario-planning process can be characterized by a series of steps, as follows (Wollenberg *et al.* 2000; Peterson *et al.* 2003; Evans *et al.* 2006):

(1) *Identify a focal issue*. To be effective, scenario planning should address a specific focal question (eg how will the ecosystem services provided by Lake Wingra change over the next 3 decades?). The focal issue is best identified with stakeholder input.
(2) *Perform systems analysis*. An assessment is required of the people, institutions, ecosystems, and their connections that define the system relevant to the focal issue. Based on this assessment, the major drivers (eg demographic change) and key uncertainties (eg the degree to which new technologies become available) are identified.
(3) *Brainstorm alternative trajectories*. The key uncertainties form a platform from which to brainstorm alternative ways in which the system could evolve. Based on this exercise, a set (usually three to five) of alternative trajectories is identified, which will help to illuminate the focal issue.
(4) *Build the scenario narratives*. Detailed stories linking the present to the future are drafted for each chosen trajectory. This is best done by a small group of individuals. Each story should track key indicators relevant to the initial focal question and should complement each other, forming a coherent, thought-provoking set.
(5) *Test the scenarios*. The draft storylines should be tested for consistency. The dynamics of the stories must be plausible. Consistency may be tested through interviews with stakeholders or by quantification.
(6) *Use the scenarios*. Once created, the set of scenarios can be used to inform policy or further research.

Teaching through application: developing scenarios for Lake Wingra

We explored the scenario-planning process in a one-credit graduate seminar involving 13 students with backgrounds in the natural sciences and interdisciplinary social–ecological programs. We focused on the practical development of a set of scenarios for the future of Lake Wingra, a small urban lake in Madison, Wisconsin, surrounded by substantial green space and used for swimming, fishing, and non-motorized boating. The scenarios were developed in collaboration with the Friends of Lake Wingra (FOLW), a community-based, non-profit organization. The process was intended to help inform an FOLW-led initiative to develop a set of goals and associated management strategies for the Lake Wingra ecosystem.

The scenario-planning group met once a week for 2 hours during the semester. Sessions were structured to alternate between (a) reviews of published scenario exercises and methods and (b) the practical development of scenarios for Lake Wingra (see WebPanel 1 for class schedule and readings). Early in the semester, we had an opportunity to participate in a public meeting organized by FOLW, at which goals for Lake Wingra were brainstormed. This gave us an understanding of the broader context to which the scenario-planning process might contribute. Based on this understanding, the focal question (step 1) for the scenario exercise was defined as: how will Lake Wingra and the ecosystem services it provides change over the next generation (ie between now and 2035)?

Next, through a process of brainstorming and discussion, we conducted a systems-based analysis exercise (step 2) and developed a conceptual model of social and ecological elements that influence Lake Wingra (Figure 2). This analysis helped build appreciation and understanding of the complex set of social and ecological drivers that affect this lake. Students found the process valuable as a practical example of systems-based thinking and as a way of moving them outside of their academic comfort zones.

Step 3 entailed the generation of alternative trajectories for the development of the city of Madison, which would have differing consequences for Lake Wingra. Alternative trajectories were brainstormed at a workshop with 10 invited stakeholders from various backgrounds. We explored trajectories in which it was very difficult or relatively easy for FOLW to achieve their goals. In addition, several "wildcard" storylines were brainstormed, in which unexpected changes in drivers (such as climate and urban population) occurred.

The ideas generated at the stakeholder workshop were distilled to identify four key trajectories that, as a set, highlighted a handful of particularly illustrative and thought-provoking futures. A small group of students fleshed out narratives for these trajectories (step 4), which were internally reviewed by the class. The revised scenarios were then discussed in one-on-one meetings with different community stakeholders, to obtain feedback on their plausibility and usefulness (step 5). Based on this feedback, the scenarios were again revised, and were then written up as a class report and formally presented to FOLW at a public meeting (Panel 1).

Reflections on the learning process

Students provided detailed written reflections on the course 8 months after completion of the scenario planning exercise described above (see WebPanel 2 for guiding questions). The course was widely regarded by the students as stimulating and fun (even though it involved a lot of work) and was very different from other courses that they had taken. All of the students stated that they

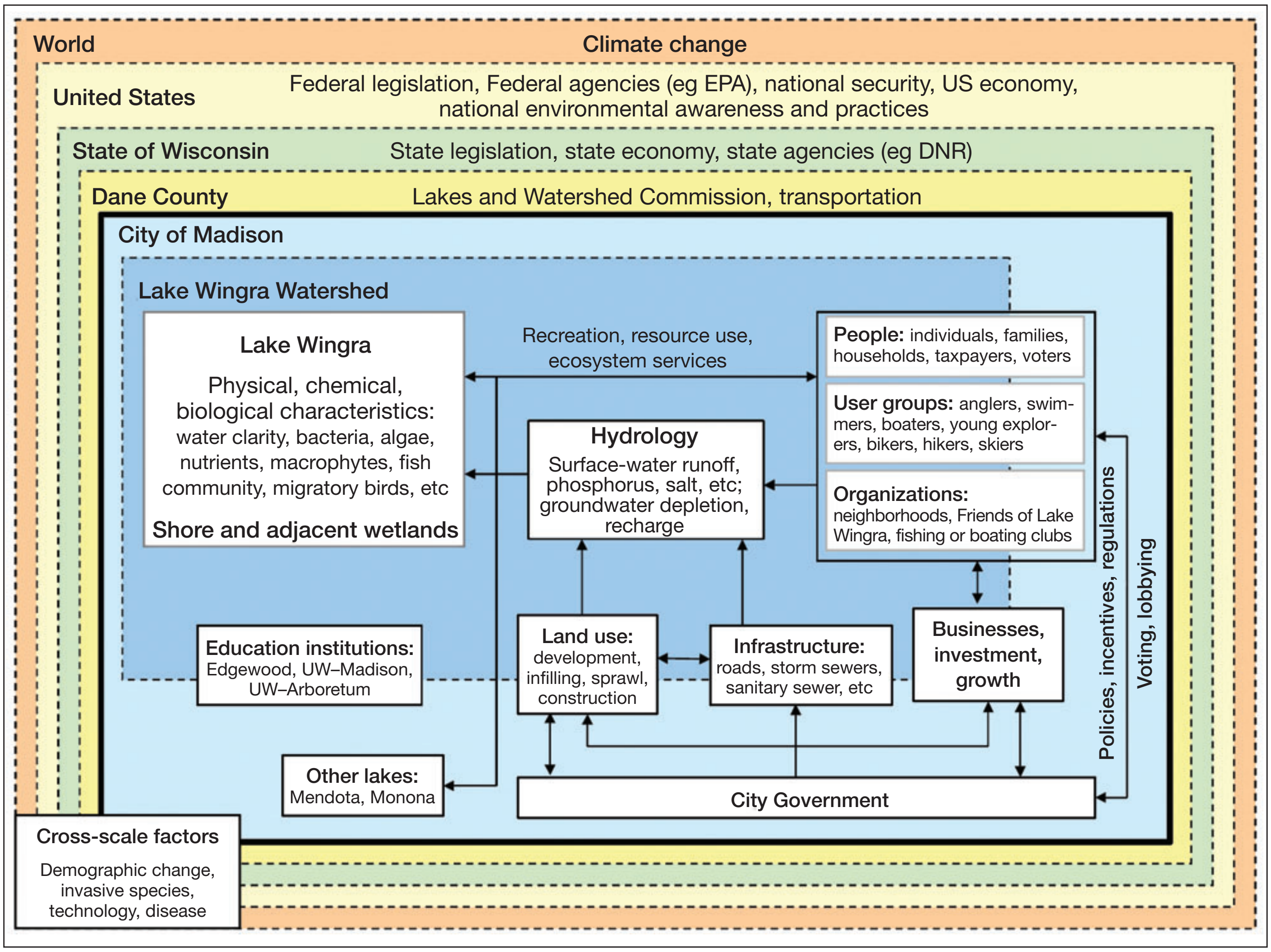


Figure 2. *Conceptual model of the Lake Wingra system, spanning drivers at several spatial scales. Based on this analysis, we defined the spatial boundary for the scenario exercise as the city of Madison, Wisconsin. This was the scale at which the most important interactions and feedbacks relevant to the Lake Wingra ecosystem were present.*

would recommend the class to others, and many expressed a desire to use scenario planning in their future careers. Based on a manuscript-planning workshop held after students had reflected on the course, we agreed that the following four key learning points emerged from our experiences.

Appreciating the prevalence of uncertainty

Exploring possibilities for the future in a narrative framework forced students to expand their notion of uncertainty. One student commented, "prior to this seminar, I mostly thought about uncertainty as error bars around a mean. Thinking about scenarios made me acknowledge the existence of qualitative unpredictability". Other students noted that the exercise highlighted that "we are working in a world of many unknowns" and that many uncertainties are driven by changing societal goals, rather than scientific issues.

Several students felt that the seminar had changed their attitude toward uncertainty; one observed that "people often treat uncertainty as a bad thing. Admitting uncertainty, and asking what policies make sense in the light of uncertainty, are critical. Uncertainty deserves to be taken off the list of bad words". Another stated, "I felt encouraged…that although uncertainty is a great challenge, it can be worked with and incorporated into policies and management plans". Although not all students were as optimistic as this, most recognized that scenario planning provided a different way of thinking about and dealing with uncertainty, as compared with traditional scientific approaches.

Working with non-academic stakeholders

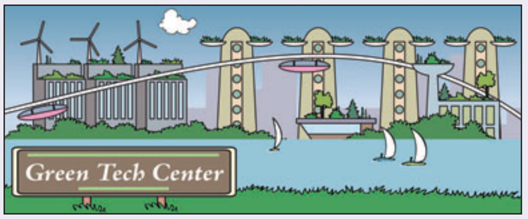
"Eye-opening", "refreshing", and "inspiring" were how some students described their interaction with non-academic stakeholders (eg government officials, agency scientists, local business leaders, and community-group representatives). Many students found the interaction with stakeholders to be the most valuable part of the class. In particular, it changed the way they perceived those outside of academia; for instance, one observed that "non-academic stakeholders demonstrated an impressive grasp

Panel 1. Lake Wingra scenarios

We developed four scenarios describing the development of the city of Madison and the consequences for Lake Wingra and the ecosystem services it provides. The scenarios were built around four key uncertainties: (1) the level of environmental awareness and green technology at the national and global level; (2) the power and influence of grassroots environmental organizations within Madison; (3) conflict between different user communities of Lake Wingra; and (4) challenges posed by invasive species. None of the scenarios present an ideal or preferred outcome, highlighting the fact that any development trajectory poses challenges and tradeoffs. The full report is available at http://limnology.wisc.edu/courses/zoo955/spring2007/index.html.

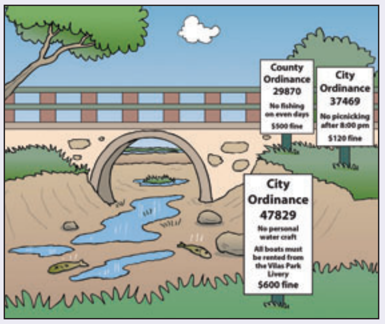
Garden State

Propelled by concern for the global environment, enormous investments are made in green technology. These technologies, from solar roofs to biofuel feedstocks grown in residential rain gardens, permeate Madison. Local environmental groups are gradually assimilated by powerful, global environmental organizations. The shift of influence to larger scales affects Madison's approaches to local environmental issues such as Lake Wingra. By 2035, the population of Madison has increased substantially and the lake system has become heavily engineered, leaving the long-term health of the lake in question.



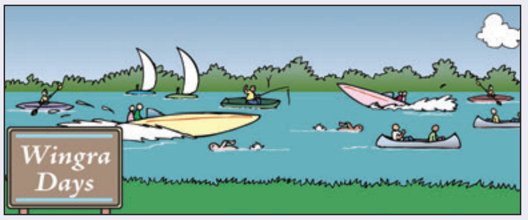
Big Green Brother

Grassroots organizations transform government and divert funding to city-wide environmental projects. Strong steps are taken to address local environmental needs, including restoration of Lake Wingra. However, over time, the new institutions become more narrowly focused and less responsive to evolving needs. The trend toward top-down management of local resources leaves a bad taste of big government in residents' mouths. This rigidity meets a severe challenge when an intense, persistent drought strikes the Madison area. By 2035, tough choices have to be made between mitigating the effects of the drought and pursuing the management goals for the Lake Wingra watershed.



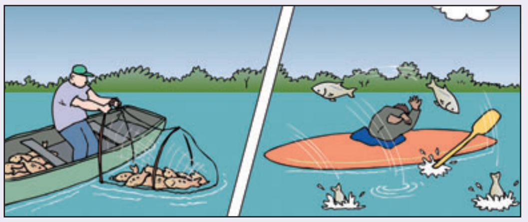
C-Clear

Local organizations develop increasingly successful innovations for managing Lake Wingra. Use of the lake intensifies, and the institutions representing the expanding user community become more diverse. However, conflict arises among the different interest groups, various coalitions form, and political gridlock ensues. Emerging issues continually challenge those who wish to conserve Lake Wingra. By 2035, the ecological health of Lake Wingra has improved, but only a fraction of the stated goals have been met.



Exotic Exchange

Success in removing an exotic invader from Lake Wingra results in progress toward a healthier lake, but creates an ecological vacuum and reveals unexpected conflicts among user groups. In 2017, a new harmful invader fills the ecological vacuum and creates a new suite of problems for Lake Wingra. This catalyzes change and refocuses management efforts. By 2035, preventing future invasions has taken center stage and fish management has reoriented around the diverse interests of different user groups.



of the issues…Their concerns did not always mirror those of scientists studying the lake. Many times, their perspectives were holistic, encompassing ecosystem-, watershed-, and community-level thinking".

The importance of listening was a central lesson for the students: "I learned that while people feel strongly about a variety of things, most are very willing to listen to academic viewpoints, provided that academics are willing to listen to them". Students also felt they gained valuable verbal and writing skills; for example, one participant responded, "I improved my writing by thinking outside of the research paper framework. I was challenged to write more clearly, concisely, and with less jargon". Another realized that "engaging people in thinking about the future of our environment requires dealing in real stories – with color, and noise, and clutter".

Students were motivated by the fact that they were contributing to a broader, non-academic process: "The participation of non-academic stakeholders reminded us that the materials we were developing would be used by people outside the class...I think this helped to motivate class participants to produce work of high quality and to complete work promptly". Others noted that stakeholder interaction "provided a much-needed, 'real world' perspective for our academic work and gave us a better sense of the broader community in which we live".

Appreciating the need for multiple viewpoints

Scenario planning is inherently interdisciplinary. The systems-based focus of scenario planning substantially expanded students' perspectives. One participant was reminded that "ideas outside of ecology are important for thinking about the future of a lake and its watershed". Another stated, "I learned that for any environmental issue, each discipline feels like it has a solution to the problem…it was eye-opening to see how everyone's solutions were so specific to their disciplines".

The contribution made by non-academic stakeholders was especially illuminating, which led one student to recognize that "science does play an important role in information gathering, but it is only one piece". Students also learned that "involving a diverse group of people brings necessary and different perspectives", which helped them to develop "a better appreciation for all the different points of view that contribute information to any policy or management plan".

Better understanding the role of science in planning processes

Students found the scenario exercise valuable in giving them the opportunity to explore the complex linkages between science and policy. Prior to the scenarios-based course, many students felt cynical about the role of science in planning processes. For instance, one student believed that "policy was written and executed without being informed by science". At the other extreme were students who felt science played a driving role: "I had the somewhat idealistic view of science playing the strong role of informant in planning processes and policy". By providing a practical experience, the course left most students with a more nuanced, but positive view about science's contribution to planning processes.

Furthermore, many students specifically stated that the course changed the way they envisioned their roles as scientists. For example, one student realized that, with respect to his work "scenario planning could be used to empower people to create their own future". Another student, working on conservation issues in developing countries, felt that the storytelling approach in scenario planning "might prove valuable in transcending cultural barriers".

Conclusions

Because of their critical role in helping society navigate the ecological problems of the 21st century (UN 2002; MA 2005c; IPCC 2007), tomorrow's environmental scientists must be confident and motivated. Our experiences suggest that scenario planning can be an effective way of allowing graduate students to experience the post-normal scientific approaches needed to address these challenges.

Because we hope that this work will encourage educators at other institutions to offer similar courses, we will discuss some of the teaching challenges that emerged. All students felt that the practical aspects of the course, especially the interactions with non-academic stakeholders, were central to their learning. Although it may be difficult to locate a stakeholder group with the time and inclination to engage such a class, our experience demonstrated that if a topic of mutual interest can be identified, stakeholders may find the scenario planning exercise as rewarding as the students did. Close interaction among participants also improves the quality of the scenario products and increases their usefulness to the stakeholder group. A second challenge stems from the fact that the value of a scenario-based approach is often evident only to those familiar with it. The notion of science as the provider of certain, factual information is deeply entrenched in modern culture, and it may be difficult to appreciate the value of a deliberately non-predictive exercise. Our advice is to approach the exercise as an experiment, drawing on other cases of successful, scenario-based exercises (eg Kahane 1999; Wollenberg *et al.* 2000; Galer 2004) as examples of potential outcomes.

We would also like to suggest several improvements to the course. Most students found that the literature review components were useful but, given the limited time, would have preferred to spend more time on the practical exercise. In particular, students expressed an interest in interactions with a wider variety of stakeholders. Many students also felt that the class would have been enriched by students with a broader range of disciplinary backgrounds. Both student and stakeholder diversity, however, entail tradeoffs in efficiency. In most cases, aiming for mid-level diversity in both dimensions may be best. The degree of participation by stakeholders will largely be determined by pragmatic considerations, and successful exercises can likely be carried out with interaction at a range of levels. Finally, many students thought that the class might have been more appropriate as a three-credit course. An option for future instructors may be to offer a course at the one-credit level, focusing on a practical exercise, or as a three-credit course, including a broader review of the literature.

Acknowledgements

We warmly thank the Friends of Lake Wingra (http://lakewingra.org), and particularly A Forbes, for the opportunity to collaborate on this exercise. B Feeny of the Department of Zoology (University of Wisconsin–Madison) provided generous graphical support. J Fox, a fellow student who participated in the course, is thanked for his contributions. Financial support was provided by the North Temperate Lakes Long Term Ecological Research site.

References

Bammer G. 2005. Integration and implementation sciences: building a new specialization. *Ecol Soc* **10**: 6.

Bocking S. 2004. Nature's experts: science, politics, and the environment. New York, NY: Rutgers University Press.

Evans K, Velarde SJ, Prieto R, *et al.* 2006. Field guide to the future: four ways for communities to think ahead. In: Bennett EM and Zurek M (Eds). Nairobi, Kenya: Center for International Forestry Research.

Funtowicz SO and Ravetz JR. 1993. Science for the post-normal age. *Futures* **25**: 739–55.

Galer G. 2004. Preparing the ground? Scenarios and political change in South Africa. *Development* **47**: 26–34.

Gibbons M, Limoges C, Nowotny H, *et al.* 1994. The new production of knowledge: the dynamics of science and research in contemporary societies. London, UK: Sage Publications.

Holling CS. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* **4**: 390–405.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: synthesis report. Geneva, Switzerland: IPCC.

Kahane A. 1999. Changing the winds. *Whole Earth Review* **Spring**.

Kahane A. 2004. Solving tough problems: an open way of talking, listening, and creating new realities. San Francisco, CA: Berrett-Koehler Publishers.

MA (Millennium Ecosystem Assessment). 2005a. Ecosystems and human well-being: multiscale assessments. Washington, DC: Island Press.

MA (Millennium Ecosystem Assessment). 2005b. Ecosystems and human well-being: scenarios. Washington, DC: Island Press.

MA (Millennium Ecosystem Assessment). 2005c. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

Manson SM. 2001. Simplifying complexity: a review of complexity theory. *Geoforum* **32**: 405–14.

Norgaard RB and Baer P. 2005. Collectively seeing complex systems: the nature of the problem. *BioScience* **55**: 953–60.

Peterson GD, Cumming GS, and Carpenter SR. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conserv Biol* **17**: 358–66.

Pilkey OH and Pilkey-Jarvis L. 2007. Useless arithmetic: why environmental scientists can't predict the future. New York, NY: Columbia University Press.

Roe GH and Baker MB. 2007. Why is climate sensitivity so unpredictable? *Science* **318**: 629–32.

Sarewitz D. 2004. How science makes environmental controversies worse. *Environ Sci Policy* **7**: 385–403.

Steffen WL, Sanderson A, Tyson PD, *et al.* 2004. Global change and the Earth system: a planet under pressure. Berlin, Germany: Springer-Verlag.

UN (United Nations). 2002. World summit on sustainable development: Johannesburg plan of implementation. New York, NY: United Nations.

van der Heijden K. 1996. Scenarios: the art of strategic conversation. New York, NY: John Wiley.

Wollenberg E, Edmunds D, and Buck L. 2000. Anticipating change: scenarios as a tool for adaptive forest management. Bogor, Indonesia: Center for International Forestry Research.

Ziman J. 2000. Real science: what it is and what it means. Cambridge, UK: Cambridge University Press.

Zurek M, Biggs R, Raudsepp-Hearne C, *et al.* 2008. Exploring future trends in ecosystem services. In: Ranganathan J, Raudsepp-Hearne C, Lucas N, *et al.* (Eds). Ecosystem services: a guide for decision-makers. Washington, DC: World Resources Institute.