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Chicago WILDERNESS

Can Biodiversity Survive Global Warming?

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Bob Sullivan and Milt Clark explore the impacts of global warming on biodiversity, and the challenge of balancing critical environmental concerns with our ever-increasing demand for energy.

> *"It is now clear that climate change is the major new threat that will confront biodiversity this century, and that if greenhouse gas emissions run unchecked through 2050 or beyond, the long-term consequences for biodiversity will be disastrous…The synergy between climate change and habitat fragmentation is the most threatening aspect of climate change for biodiversity, and is a central challenge facing conservation."*
>
> —Thomas Lovejoy and Lee Hannah,
> Climate Change and Biodiversity, 2005[1]

> *"The world is facing twin energy-related threats: that of not having adequate and secure supplies of energy at affordable prices and that of environmental harm caused by consuming too much of it…The need to curb the growth in fossil-energy demand, to increase geographic and fuel-supply diversity and to mitigate climate-destabilising emissions is more urgent than ever."*
>
> —International Energy Agency (IEA),
> World Energy Outlook 2006[2]

Lovejoy and Hannah's quote from their recent book points out both the threat that global climate change poses to biodiversity and the challenge that we face as stewards of biodiversity. Chicago Wilderness members must take immediate steps to address this challenge. We must plan now for a future where global warming is a significant force for changes in biodiversity, particularly when the situation will be exacerbated by the pervasive habitat fragmentation that we already face. The IEA quote points to a different, but closely related threat to biodiversity that also requires immediate action: increasing global energy consumption that can be met only by increased use of greenhouse gas–emitting fossil fuels. To reduce harm to biodiversity, the environment, and to ourselves, we must somehow decrease greenhouse gas emissions while meeting our ever-increasing demand for energy. These challenges are enormous and the time is short. Our ability to make good choices and key changes now with respect to both climate change and energy may have profound and lasting effects on biodiversity in the future.

Global Climate Change Impacts

The impacts of global climate change on biodiversity are not merely concerns of a far-off "worst-case" future; they are happening and observable now, in a variety of locations around the world. Most of us are already aware of the recent world-wide decline in amphibian species, the potential listing of polar bears as a threatened species, and the widespread bleaching of coral, all of which are directly linked or strongly suspected of being linked to global climate change. Contributors to Climate Change and Biodiversity and others[3-7] document numerous instances of species response to global climate change in the United States and elsewhere, including changes in species distribution and abundance, and life cycle shifts for all major groups of plants and animals.

Global climate change has both direct and indirect effects on biological systems. Direct effects include those arising from increased temperature and increased carbon dioxide (CO_2) levels associated with global climate change. These direct effects give rise to numerous potentially serious indirect effects, such as changes to hydrologic cycles (precipitation and evaporation) and more extreme weather events[8-10]. These changes can influence biodiversity in many ways (both positive and negative), such as changing the timing of critical events that affect plant and animal species[4]. For example, increased temperatures can cause caterpillars to hatch earlier in spring, which can affect birds dependent on those species for food; birds whose nesting and hatching times are controlled by photoperiod may be unable to adjust to the changed timing of caterpillar emergence. When the birds' chicks hatch, the caterpillars may have been eaten by other species or have metamorphosed into butterflies, and the chicks may starve as a result. Global climate change–related increases in CO_2, temperature, nutrient, and water levels can lead to changes in plant growth that will affect animals that eat vegetation, and can eventually change the species composition in plant communities[6]. These are but a few examples of the effects that global climate change can have on biodiversity.

Illinois and the Great Lakes region have already warmed because of greenhouse gas emissions. While climate change models can operate only at scales larger than the Chicago Wilderness region, it would be expected that the Chicago area will have more extreme weather events leading to more droughts and flooding[11]. As additional warming occurs, a range of ecological changes and effects on wildlife are expected, with the most significant being effects on aquatic and other species that are dependent on water bodies for breeding and feeding, such as fish, amphibians, and waterfowl[11-13]. The overall number of wetlands, especially prairie potholes and similar depression wetlands, are expected to decrease. Fluctuations in water levels within wetlands will cause changes in nutrient levels and may also enable the release of toxic metals such as mercury. Changes in the timing and duration of flooding events will reduce the number of effective breeding sites for waterfowl.

In many lakes, including Lake Michigan, changes in speciation are likely as water temperatures increase and water levels decline[12-13]. Cold-water species such as salmonids (e.g., coho salmon and lake trout) will be under increased stress. Less desirable species, such as carp or invasive species that can more readily adapt to changing habitat conditions, will be more common. Temperature increases also lower oxygen levels in the summer and create "dead zones," which cannot support life. If dead zones persist, they can give rise to toxic algal blooms and damage fisheries. Finally, the depth of Lake Michigan is projected to decrease by three feet within the next 100 years, exposing more shoreline and thus affecting ecological habitats adjacent to the lake[12].

Ranges of trees such as red pine, black walnut, and sugar maple are expected to contract or expand as the climate in the Great Lakes region becomes hotter and, in some areas, drier[11]. The range of red pine may virtually disappear throughout the region, while that of the black walnut may expand. Such changes in the composition of forests could have profound effects on a variety of species.

Ecological Response to Climate Change

In general, affected species have three possible responses to global climate change, which can best be summed up as "change, move, or die." More scientifically, species can 1) adapt by changing life cycles or by evolving; 2) shift habitat ranges to a more suitable, generally cooler climate (usually upward in elevation, or northward in the Northern Hemisphere); or 3) become extirpated from a region or extinct altogether. There is evidence that all three responses are occurring around the world, including the United States. Some species are already on the move toward the poles or to higher elevations[14-15]. Some species are hatching earlier, blooming earlier, or exhibiting other phenological changes[4,16]. Some are evolving rapidly; notably, in one case, a population of crickets is developing longer wings, perhaps to enable them to fly farther in search of suitable habitat[17]. And some are dying, with at least one species thought to be extinct as a direct result of global warming[14,18-20]. In Nature, one analysis—based on mid-range climate model scenarios derived from three sample areas that cover 20% of the earth's land surface—estimated that, by 2050, the extinction rate will range from 15% to 37% of all species in these areas[18].

There are and will be interactions between these three responses to global climate change. For example, the removal (whether via range shifting or extinction) of species from an ecosystem may give rise to an influx of new species to fill the empty niches. Removal of species, timing changes for significant biological events, and other global climate change effects will also lead to evolutionary responses, for example, in response to changes in predator-prey relationships[17].

Furthermore, it is believed that the net effects of global climate change will favor invasive species—those opportunists that can quickly exploit the new ecological niches that will open up as native species that cannot adapt to the change "move or die"[21-25]. The additional stresses on ecosystems (along with higher temperatures) will also likely favor vector-borne diseases[26] such as the mosquito-spread West Nile virus that has devastated populations of many bird species in the Chicago area. The total effect of global climate change on biodiversity cannot be forecast accurately; ecosystems are very complex, many mechanisms are incompletely understood or even unknown, and the models for predicting climate change vary in the degree of warming that is predicted. However, there is agreement that the effects are likely to be profound.

Of course, ecosystems and their constituent species have always had to contend with climate change; studies examining the fossil record show that climate has changed substantially and sometimes quickly in ages past. However, the current situation differs from situations we know of in the near and distant pasts in several important respects. The rate of change in atmospheric CO_2 levels is unprecedented within the past several hundred thousand years, and the levels are the highest observed in the past 650,000 years[10,27]. Global temperature is tightly correlated to CO_2 levels; if the current rate of change in CO_2 level continues, temperatures may approach or exceed those seen for the past several hundred thousand years as well[10]. In Overpeck, Cole, and Bartlein's words, "No region on Earth is safe from a surprise abrupt climate change, and most regions will soon be experiencing their warmest climate in two million years or more."[27]

Another difference between the current situation and past periods of climate change is the extensive habitat fragmentation and alteration that now exists, primarily as a result of agriculture and urban and other human development. Habitat fragmentation may greatly exacerbate the damaging effects of global climate change by restricting habitat range; species that could once move long distances freely to seek more favorable habitat are now faced with numerous man-made barriers, such as extensive agricultural lands and urban areas[17,28]. Prevention of range shifting because of habitat fragmentation may also favor the increased proliferation of invasive species. Human-made barriers might prevent native species from occupying niches left by species in decline; invasive species can often more readily occupy these niches[23]. Habitat fragmentation also reduces the genetic pool from which species can draw to evolve new mechanisms to cope with change[29].

Because global climate change, exacerbated by habitat fragmentation, is a major threat to biodiversity, any steps we can take to limit climate change will likely help diminish the effects of climate change on biodiversity. One step is to reduce the amount of greenhouse gases humans put into the atmosphere, a significant contributor to climate change. The burning of fossil fuels is the primary source of human-made greenhouse gases, and it may be tempting to assume that we can solve this problem if we simply stop burning fossil fuels, or burn less of them; that if we can just crank up the renewable energy sources, like wind, solar, and geothermal, and maybe build some new nuclear power plants (as odious as that may be for some of us), we can turn this around. These are very big "ifs"; to see just how big, let's turn to the topic of global and national energy demand.

Energy and Climate Change

> *"Engineers whose work familiarizes them with energy statistics; far-seeing industrialists who know that energy is the principal factor which must enter into all planning for the future; responsible governments who realize that the well-being of their citizens and the political power of their countries depend on adequate energy supplies—all these have begun to be concerned about energy resources."*
>
> —Rear Admiral Hyman G. Rickover, U.S. Navy,
> "Energy Resources and Our Future," 1957 speech[30]

Hyman Rickover's prophetic speech on energy resources predicted both the inevitability and the consequences of the end of the "Fossil Fuel Age." We may be nearing the end of that age, and the world's insatiable thirst for energy is hastening that end. Whether that age ends because we simply use up the remaining viable fossil fuel sources or because we choose different, sustainable energy resources remains a critical unanswered question.

The Energy Information Administration (EIA) is the U.S. Department of Energy's keeper of energy statistics and center for forecasting and analysis. Its 2006 annual

"The outlook for moving away from fossil fuels is bleak unless governmental and societal interventions (i.e., incentives, conservation, and regulations) are initiated."

report on international energy demand forecasts world energy consumption to increase by 71% from 2003 to 2030, with fossil fuels continuing to supply much of the energy used worldwide[31]. The report goes on to state that the projected growth in energy demand will be driven by robust economic growth, with demand in developing countries (including China and India) approximately three times that of industrialized countries. Despite predicted rapid growth in renewable energy use, world demand for energy is forecast to rise faster, and the total share of world demand met by renewable energy is projected to increase by just 1%, from 8% to 9%, between now and 2030. Much of this projected growth results from new hydroelectric projects in the developing world, which is not the best choice of technology for preserving biodiversity.

Although new nuclear plants may be built in the U.S. and elsewhere, coal-based electrical energy generation, which produces the highest levels of carbon dioxide per kilowatt produced, will continue to dominate new electrical capacity. Therefore, the percentage of total world demand that will be met by nuclear power is forecast to actually decrease from 6% to 5% by 2030. In fact, the relative contributions of the various energy sources are forecast to remain virtually unchanged, but the amount of energy produced will increase enormously. This means a massive increase in the consumption of fossil fuels, which account for 86% of current energy consumption. The EIA report spells out the consequences quite plainly:

> *"World carbon dioxide emissions continue to increase steadily…from 25.0 billion metric tons in 2003 to 33.7 billion metric tons in 2015 and 43.7 billion metric tons in 2030… Three-fourths of the projected increase in carbon dioxide emissions results from fossil fuel consumption."*

And the outlook for the United States? EIA's Annual Energy Outlook 2007[32] paints a picture remarkably similar to the global outlook; steady growth in demand but little change in the relative mix of fuel sources. Despite rapid growth projected for biofuels and other nonhydroelectric renewable energy sources, and the addition of new nuclear power plants in the United States, oil, coal, and natural gas are still projected to provide roughly the same share (86%) of the total energy supply in 2030 as in 2005 (assuming no changes in existing laws and regulations). This is because the expected rapid growth in the use of biofuels and other nonhydropower renewable energy sources begins from a very low current share of total energy use. The share of total electricity supplied from nuclear power is projected to fall, despite the projection of new plant construction.

In other words, supply will lag behind demand and we will increase our use of fossil fuels substantially. The United States has substantial reserves of coal and is certain to use them to meet a significant portion of the increased energy demand. According to EIA's International Energy Outlook 2006, in the United States, coal production is forecast to roughly triple by 2030. China and the United States will lead the world in adding coal-fired capacity by adding 546 gigawatts and 154 gigawatts of new generation, respectively[31]. (As a point of reference, the average United States nuclear power plant generates about 1 gigawatt.) The outlook for moving away from fossil fuels is bleak unless governmental and societal interventions (i.e., incentives, conservation, and regulations) are initiated. Encouragingly, both the IEA and EIA reports note that energy consumption and greenhouse gas emissions may be significantly reduced by strong and immediate government action to "steer the energy system onto a more sustainable path"[2,31].

The EIA reports are forecasts, of course, based on many assumptions. They may be wrong; they have been wrong before[33]. But they would have to be very wrong to change the picture substantially, and increased fossil fuel use and greenhouse gas emission are in our future if we "stay the course."

Spurred in part by high oil prices arising from increased demand, coupled with a need for energy security, the United States is already engaged in significant efforts to increase domestic energy supplies and to build the needed transmission capacity to deliver the energy from its sources to markets. The Energy Policy Act of 2005 explicitly addresses the nation's pressing energy concerns and contains numerous provisions to facilitate energy production and transmission improvements, including the development of renewable energy and of oil shale and tar sands, "alternative" oil resources generally involving higher energy inputs to extract oil, and potentially involving significant environmental issues[33,34]. Various energy companies are actively exploring, developing, and testing technologies for extracting these resources, both in the United States and elsewhere (see http://ostseis.anl.gov). The U.S. Department of Energy is currently studying electric and pipeline transmission congestion in the United States[35], and is in the process of designating thousands of miles of potential energy corridors (see http://corridoreis.anl.gov) on Federal lands as preferred locations for future energy transmission development. There are many other examples, but the intent is clear; the United States is going to push hard to develop new energy supplies and the infrastructure needed to deliver it.

Potentially serious environmental impacts will result from the construction and operation of the energy and transportation infrastructure needed to support the country's energy supply. Power plants, mines, wells, wind turbines, refineries, transmission lines, roads, and pipelines will all be needed. Their development will affect biodiversity by further fragmenting habitat and adding to pollution loads, water consumption, waste generation, and of course, in some cases, greenhouse gas production. There is no free lunch when it comes to energy; even windmills kill birds and bats and have significant visual impacts[36]. It will cost a great deal to further develop the country's energy infrastructure; whatever resources are needed will likely be taken from other worthy causes (perhaps including conservation), because failure to meet our energy needs in a significant way is simply untenable. Massive economic and social disruption would likely follow any such crisis[33,37]. Biodiversity will be a much smaller concern at that point, and it will suffer accordingly.

We are faced then on one hand, as guardians of biodiversity, with a critical need to reduce greenhouse gas production. By most accounts, we have very little time. Unfortunately, our appetite for energy requires increased supply, which will not only increase our greenhouse gas production but affect biodiversity in many harmful ways. We are between a rock and a hard place, and the stakes are very high. For biodiversity, this could be the "perfect storm." Already pushed to the brink in many cases by habitat loss, invasive species, and pollution, earth's flora and fauna now face major impacts from global climate change, combined with further fragmentation of habitats and increased pollution loads from massive energy development to meet the needs of a rapidly expanding world population. It is a grim picture, and it is already coming to pass. We must act now to do what we can to prevent this outcome, or at least to minimize the harm. We cannot "stay the course."

Of course much is being done, but largely in the area of education and research. Awareness of global climate change and its impacts on biodiversity is increasing rapidly. Scientists and engineers across the globe are working on cleaner energy technologies such as integrated gasification combined-cycle coal technology and other methods for preventing greenhouse gas emissions, such as carbon sequestration. In many countries, renewable energy resources are being developed at an encouraging pace. Policy makers are beginning to address the many complex issues that must be faced, with politicians and elected officials beginning to devote time and resources to addressing the problem[38,39]. Corporations and private citizens are demanding accountability and accepting responsibility for participation[40]. But this is barely a start—much time has been wasted debating the existence and causes of recent global warming. The debate has shifted from whether or not climate change is occurring to one of solutions and adaptation. The country needs an aggressive national energy policy to combat the growing threat from global warming. There is an enormous amount of work to be done, and time is of the essence[41,42]. Fortunately, we have tremendous resources at our disposal—if we have the will to use them.

Chicago Wilderness members are aware of global climate change, and some are taking action. Chicago Wilderness hosted a well-attended session on global climate change at the Chicago Wilderness Congress last November. There is a set of research questions pertaining to this issue in the Science Team's draft Natural Science Research Agenda, and global climate change is a frequent topic of discussion at team meetings and workshops. The Chicago Metropolitan Agency for Planning is leading an effort to submit a proposal to the Environmental Protection Agency (EPA) to fund a Chicago-region conference on the topic of global climate change. The Chicago Botanic Garden is submitting a proposal to the National Science Foundation that would investigate the effects of climate change on the phenology and growth of plants, using wild plant populations and replicated plots in botanic gardens across the country.

These are important first steps. As stewards of biodiversity in this region, we must act, as a group of organizations, as individual organizations, and as individuals. First, we must talk about this issue, as unpleasant as that may be, amongst ourselves and with our families and friends. We must raise awareness in our communities and our places of work. Second, we must learn; learn about global climate change and biodiversity, learn about energy, and learn how we can make a difference. We have difficult but critical choices ahead about how we meet our energy needs while minimizing harm to the environment; we cannot make good choices without a clear understanding of energy issues. As we learn, we must educate others. Third, we must advocate for change at every level. We must speak for biodiversity and demand that it be considered in decision making concerning global climate change and energy. Fourth, we must begin the scientific studies to assess the current and likely future impacts of global warming to the Chicago Wilderness region, and to plan how we will sustain biodiversity in a world of changing climate.

"We must speak for biodiversity, and demand that it be considered in decision making concerning global climate change and energy."

Finally, we must take steps to reduce our own energy consumption. Every one of us can do that, whether by replacing incandescent bulbs with energy-saving compact fluorescent bulbs, buying Energy Star certified appliances (www.energystar.gov), buying a hybrid car, or riding a bike to work. Saving energy is easy and it also saves money, producing a win-win result. Furthermore, wasting energy raises ethical issues, particularly considering the known impacts of greenhouse gas emissions on the environment, on species that share the planet with us, and on the energy needs of future generations.

To close, another quote from that same remarkable 1957 speech by Hyman Rickover:

> *"Our past history and security have given us the sentimental belief that the things we fear will never really happen—that everything turns out right in the end. But, prudent men will reject these tranquilizers and prefer to face the facts so that they can plan intelligently for the needs of their posterity."*

Global warming is a fact. Let us face it and begin our planning now.

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References

1. Lovejoy, T., and L. Hannah, editors. 2005. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

2. International Energy Agency (IEA). 2006. *World Energy Outlook 2006: Summary and Conclusions*. Available at: http://www.worldenergyoutlook.org/summaries2006/English.pdf Accessed 20 January 2007.

3. Parmesan, C. 2005. Biotic response: range and abundance changes. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

4. Root, T., and L. Hughes. 2005. Present and future phenological changes in wild plant and animals. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

5. Pounds. J., M. Fogden, and K. Masters. 2005. Responses of natural communities to climate change in a highland tropical forest. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

6. Parmesan, C., and H. Galbraith. 2004. *Observed Impacts of Global Climate Change in the U.S.* Prepared for the Pew Center on Global Climate Change. November. Available at: http://www.pewclimate.org/docUploads/final_ObsImpact.pdf Accessed 20 January 2007

7. Root, T., and S. Schneider. 2002. Climate change: Overview and implications for wildlife. In Schneider, S. and T. Root, editors, *Wildlife Responses to Climate Change: North American Case Studies*. Island Press, Washington DC.

8. Karl, T., and K. Trenberth. 2005. What is climate change? In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

9. Hulme, M. 2005. Recent climate trends. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

10. International Panel on Global Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis; Summary for Policymakers. February 2007. Available at: http://www.ipcc.ch/SPM2feb07.pdf

11. Sousounis, P., and J. Bisanz (eds.). 2000. *Preparing for a Changing Climate: Great Lakes Overview*. University of Michigan. ISBN 0-9705619-0-3.

12. International Joint Commission, Water Quality Board. 2003. *Climate Change and Water Quality in the Great Lakes Basin*, ISBN 1-894280-42-3, August 2003.

13. Kling, G. 2003. Confronting Climate Change in the Great Lakes Region, Union of Concerned Scientists, 2003.

14. Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *The Annual Review of Ecology, Evolution, and Systematics* 37:637–69. Available at: http://cns.utexas.edu/communications/File/AnnRev_CCimpacts2006.pdf. Accessed 20 January 2007.

15. Wilson, R., D. Gutiérrez, J. Gutiérrez, D. Martínez, R. Agudo, and V. Monserrat. 2005. Changes to the elevational limits and extent of species ranges associated with climate change. *Ecology Letters* 8(11):1138–1146. doi:10.1111/j.1461-0248.2005.00824.x

16. Bradley, N., A. Leopold, J. Ross, and W. Huffaker. 1999. Phenological changes reflect climate change in Wisconsin. *Proceedings of the National Academy of Sciences of the United States of America* 96(17):9701–9704. doi:10.1073/pnas.96.17.9701. Available at: http://www.pnas.org/cgi/reprint/96/17/9701.pdf Accessed 20 January 2007.

17. Thomas, C. 2005. Evolutionary effects of climate change. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

18. Thomas, C., A. Cameron, R. Green, M. Bakkenes, L. Beaumont, Y. Collingham, B. Erasmus, M. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. van Jaarsveld, G. Midgley, L. Miles, M. Ortega-Huerta, A. Peterson, O. Phillips, and S. Williams. 2004. Extinction risk from climate change. *Nature* 427:145–148 (8 January 2004) | doi: 10.1038/nature02121. Available at: http://www.fishclimate.ca/pdf/Extinction_risk_from_climate_change_Nature_2004.pdf Accessed 20 January 2007.

19. Pounds, J., and R. Puschendorf. 2004. Ecology: clouded futures. *Nature* 427:107–109 (8 January 2004). Available at: http://www.nature.com/nature/journal/v427/n6970/full/427107a.html Accessed 20 January 2007.

20. Pounds, J., M. Bustamante, L. Coloma, J. Consuegra, M. Fogden, P. Foster, E. La Marca, K. Masters, A. Merino-Viteri, R. Puschendorf, S. Ron, G. Sánchez Azofeifa, C. Still, and B. Young. 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* 439:161–167 (12 January 2006). Available at: http://www.nature.com/nature/journal/v439/n7073/full/nature04246.html Accessed 6 March 2007.

21. Thomas, C. 2003. Climate change and habitat fragmentation. In *Global Climate Change and Biodiversity*. University of East Anglia, Norwich, UK, pp 22–23, April.

22. Dukes, D. 2003. Hotter and weedier? Effects of climate change on the success of invasive species. In *Global Climate Change and Biodiversity*. University of East Anglia, Norwich, UK. April 2003.

23. Lovejoy, T. 2005. Conservation with a changing climate. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

24. Thuiller, W., Richardson, D., and G. Midgely. 2007. Will climate change promote alien plant invasions? In Nentwig, W. ed., *Biological Invasions*, Ecological Studies, Vol. 193, Springer-Verlag, Berlin Heidelberg, pp. 197–211.

25. Tilman, D., and C. Lehman. 2001. Human-caused environmental change: Impacts on plant diversity and evolution. *Proceedings of the National Academy of Sciences of the United States of America* 98(10):5433–5440. Available at: http://www.pnas.org/cgi/reprint/98/10/5433.pdf Accessed 20 January 2007.

26. Drake, B., L. Hughes, E. Johnson, B. Seibel, M. Cochrane, V. Fabrey, D. Rasse, and L. Hannah. 2005. Synergistic effects. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

27. Overpeck, J., J. Cole, and P. Bartlein. 2005. A "paleoperspective" on climate variability and change. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

28. Hannah, L., T. Lovejoy, and P. Schneider. 2005. Biodiversity and climate change in context. In Lovejoy, T., and L. Hannah, editors. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut.

29. Templeton, A., R. Robertson, J. Brisson, and J. Strasburg. 2001. Disrupting evolutionary processes: the effect of habitat fragmentation on collared lizards in the Missouri Ozarks. *Proceedings of the National Academy of Sciences of the United States of America* 98(10):5426–5432. Available at: http://www.pnas.org/cgi/reprint/98/10/5426.pdf Accessed 20 January 2007.

30. Rickover, H. 1957. *Remarks Prepared by Rear Admiral Hyman G. Rickover, USN, Chief, Naval Reactors Branch Division of Reactor Development U.S. Atomic Energy Commission and Assistant Chief of the Bureau of Ships for Nuclear Propulsion Navy Department for Delivery at a Banquet of the Annual Scientific Assembly of the Minnesota State Medical Association St. Paul, Minnesota May 14, 1957.* Available at: http://ia331312.us.archive.org/3/items/rickover0557/rickover0557.pdf Accessed 20 January 2007.

31. Energy Information Administration. 2006b. *International Energy Outlook 2006*. Report DOE/EIA-0484(2006). Available at: http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2006).pdf Accessed January 20, 2007.

32. Energy Information Administration. 2006a. *Annual Energy Outlook 2007 with Projections to 2030 (Early Release)—Overview*. Report DOE/EIA-0383(2007). Release date: December 2006. Available at: http://www.eia.doe.gov/oiaf/aeo/key.html Accessed January 20, 2007.

33. Heinberg, R. 2007. The closer we get, the worse it looks. *MuseLetter* 177 (January). Available at: http://www.opednews.com/articles/genera_richard__070107_the_closer_we_look_2c_.htm Accessed Jan. 20, 2007.

34. Bartis, J., T. LaTourette, L. Dixon, D. Peterson, and G. Cecchine. 2005. Oil shale development in the United States: Prospects and policy issues. Available at: http://www.rand.org/pubs/monographs/2005/RAND_MG414.pdf Accessed 20 January 2007.

35. United States Department of Energy (USDOE). 2006. *National Electric Transmission Congestion Study*. August, 2006. Available at: http://www.oe.energy.gov/DocumentsandMedia/Congestion_Study_2006-9MB.pdf Accessed 20 January 2007.

36. United States Department of the Interior (USDOI), Bureau of Land Management (BLM). 2005. *Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States, Including Proposed Amendments to Selected Land Use Plans*. FES 05-11. June.

37. Abraham, S. 2001. Speech presented at the U.S. Chamber of Commerce National Energy Summit, Washington D.C., March 21, 2001. Excerpt available at: http://www.energy.gov/about/4778.htm

38. Samuelsohn, D. 2007. With select panel, Pelosi vows to "raise the visibility" of global warming. *Energy and Environment Daily*, January 19, 2007. Available at: http://www.eenews.net/EEDaily/2007/01/19/#1 Accessed 20 January 2007.

39. Baltimore, C. 2007. Six US senators back mandatory greenhouse gas cuts. *Washington Post*, 12 January 2007. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2007/01/12/AR2007011201611.html Accessed January 20, 2007.

40. Associated Press. 2007. GE, AES team up to cut greenhouse gases. MSNBC, January 16, 2007. Available at: http://www.msnbc.msn.com/id/16655418/ Accessed 20 January 2007.

41. Clark, M. 2006. Taking action on global warming (editorial), *Human and Ecological Risk Assessment* 12(6):1013–1017.

42. HM Treasury. 2006. Stern Review: The Economics of Climate Change. October 2006. Available at: http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Nutrient Farming: A Means to Finance Large-Scale Wetland Restoration

Donald Hey, Jill Kostel, and Gary Sullivan
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Utilizing an economic approach to conservation, Donald Hey, Jill Kostel, and Gary Sullivan propose a financial model for saving and restoring wetlands

Abstract
Most human-related environmental problems are widely recognized and their physical, chemical, and biological causes are reasonably well understood. In most cases, neither the cause nor the effect (problem) is assessed economically. We believe that if we as a society are to solve our profound environmental problems, we need to begin to create markets for the products that environmental solutions can offer. For example, wetland restoration could improve water quality, increase biodiversity and wildlife habitat, and provide needed floodwater storage. The Wetlands Initiative has created a restoration strategy, called "nutrient farming," that encourages large-scale wetland restoration by creating a market that compensates landowners who restore wetlands. The "harvest" will be nutrient (e.g., nitrogen, phosphorus, or carbon) removal credits to be sold to point source dischargers who need to meet stricter water quality standards. To be successful, nutrient farming must be viewed as a business enterprise, an economically efficient means to manage environmental problems. This paper reviews the environmental problems caused by the massive loss of wetlands in the upper Midwest since European settlement, suggests nutrient farming as a vehicle to remedy those problems, and explores the relationship between nutrient farms and biodiversity.

Introduction: The Problems
Many environmental problems in the Midwest, such as poor water quality, flood damage, and vanishing biodiversity and wildlife habitat are attributable to the loss of millions of acres of wetlands over the past 200 years. Extensive agriculture drain tile systems and narrow, incised outlet ditches have replaced the shallow, vegetated swales and meandering streams that once served as the main surface drainage conduits. Instead of days, it takes only hours for today's modern drainage systems to efficiently drain the surface and ground water out of the fields into streams and rivers (Hey 2002). Consequently, our altered river systems cost taxpayers billions of dollars in flood damage each year.

Within the Upper Mississippi River Basin agricultural practices, including the application of commercial fertilizers or manure and the production of legumes, are the principal source of nitrogen in our rivers and streams (Goolsby et al. 1999). Fertilizer is the largest contributor of nitrogen to the Mississippi River, as the benefits of increased nitrogen fertilizer application and increased crop production have become well established. The highest fertilizer usage and nitrate-nitrogen (NO^3-N) yields occur in the Corn Belt (Illinois, Indiana, and Iowa). The combination of excessive fertilizer use with rapid agricultural drainage paints a bleak future for water quality.

In 2001, the United State Environmental Protection Agency (U.S. EPA) determined that the nation needs to reduce excess nutrients, such as nitrogen and phosphorus, in receiving water bodies (U.S. EPA 2001). Nutrient overloads are responsible for a number of serious environmental issues in both inland and coastal waters including excessive algal growth, fish kills, increased sedimentation rates, low dissolved oxygen concentrations, and a depletion of desirable flora and fauna. Currently, the nutrient-laden waters reaching the Gulf of Mexico have led to the development of a massive "Dead Zone." To eliminate the impact of excess nutrients in our water bodies, the national plan calls for all states to write and enact water quality standards for total nitrogen (TN) and total phosphorus (TP) or to adopt the proposed federal criteria. The proposed criteria for Ecoregion VI, the Corn Belt, and Northern Great Plains, are 2.18 mg TN/L and 0.076 mg TP/L (U.S. EPA 2000).

Engineers estimate that the impending water quality standards will cost Illinois ratepayers more than $5 billion to install the best "concrete and steel" technology available and $500 million annually to operate these facilities (Zenz 2003). However, this investment can neither produce effluent water that meets the proposed criteria nor will it address regional watershed demand for flood control, suspended sediment reduction, open space, and wildlife habitat.

Proposed Solution

Restored wetlands can provide an ecological solution to the problems of impaired water quality and floodwater storage (e.g., Mitsch and Day 2006, U.S. EPA 1995). Although we know that restored wetlands are desirable, no one has yet developed a financing scheme large enough to effect large-scale restoration. Some state and federal programs, foundations, and private organizations do finance some wetland restoration. However, the cost and the scale of restoration to solve current nutrient and flood storage issues are enormous. It will take an estimated 5-13 million acres of restored wetlands in the Mississippi River Basin to significantly reduce the nutrient load reaching the Gulf of Mexico (Mitsch et al. 2001). Current restoration and conservation programs will contribute just a small fraction to the nutrient management requirement. Market-based or economic strategies are needed to finance this type of large-scale wetland restoration. Simply put, wetlands need to make money.

The U.S. EPA (2004) has been actively supporting the implementation of water quality credit trading programs to improve or preserve water quality. Credit trading programs have been established for different scales of watersheds, ranging from two sources in a minor watershed to multiple stakeholders in the Chesapeake Bay. The two main trading approaches are "cap and trade" systems and offset programs. Cap and trade programs have been implemented in watersheds with multiple point sources, such as municipal and industrial treatment plants, and have improved water quality by setting a limit on the total loading within the watershed from a group of regulated (point dischargers) sources. In an offset program, point sources seek

"In comparison to other credit-based programs that focus on watershed trading opportunities between municipalities or point and nonpoint sources, nutrient farming centers on the use of wetlands."

offsets, or credits, from unregulated nonpoint sources, such as farmers who adopt best management practices (BMPs) or participate in cooperative conservation programs to improve water quality. With either type of program the exchange of credits allows a water quality goal to be met through the implementation of the most cost-effective nutrient reduction methods within a particular watershed and provides an economic incentive to landowners to implement practices that improve water quality.

The Wetlands Initiative (TWI) has developed an alternative nutrient reduction credit trading strategy that we propose provides a solution for restoring wetlands, improves water quality in our streams and rivers, and overcomes the lack of economic incentive to return land back to floodplain wetlands. This ecological and economic strategy is called "nutrient farming" (Hey et al. 2005a). In comparison to other credit-based programs that focus on watershed trading opportunities between municipalities or point and nonpoint sources, nutrient farming centers on the use of wetlands. Through this strategy, the restoration of floodplain wetlands can be financed by the purchase of nutrient removal credits either through an open market or long-term contracts.

Specifically, nutrient farms are constructed or restored wetlands designed, built, and operated for the primary purpose of removing nutrients, trapping sediments, and storing floodwaters. Rather than growing corn and soybeans, a nutrient farmer "grows" wetlands. The "harvest" is the excess nitrogen and phosphorus removed from the incoming surface water and carbon dioxide, which is removed from the atmosphere. The farmer can manage the land to optimize the natural wetland processes that sequester or remove phosphorus, nitrogen, and carbon. Unlike BMP strategies, nutrient reduction credits can be verified because nitrogen and phosphorus concentrations can be measured at the intake and outfall of the nutrient farm. To quantify carbon sources and sinks, carbon fluxes (i.e., carbon dioxide uptake, greenhouse gas emissions) and carbon content in the vegetation, soils, and sediments are the key measurements needed. Landowners then sell nutrient reduction credits to other crop or livestock farmers, municipalities, or industries that release excess nutrients to surface waters and cannot cost effectively remove these nutrients themselves.

TWI has performed a number of economic studies to demonstrate the efficacy of nutrient farming, including a study to compare the economics of nutrient farming to traditional "concrete and steel" treatment technologies (Hey et al. 2005b) and an analysis of nitrogen trading scenarios in the Illinois River Basin (Kostel et al. 2007). These studies demonstrate that large-scale restored wetlands would provide important economic benefits as well as environmental benefits for humans and wildlife; benefits that are unavailable through the use of traditional technologies.

Nutrient Farming and Biodiversity

Although nutrient farms are managed wetlands, we believe the best and most efficient nutrient farms will be those that provide the biodiversity, hydrology, and structure of presettlement wetlands. Nutrient farms function biologically and chemically in the same manner as a natural wetland system. In a 'shallow marsh' nutrient farm system, nitrogen is converted to harmless nitrogen gas (N_2) by denitrifying bacteria, while phosphorus and carbon are taken up by plants and/or sequestered in wetland organic materials and soils (Walbridge and Struthers 1993; Phipps 1997). These biogeochemical processes are dependent upon effective interactions among the various nutrients, biological agents, and soil elements. All of these interactions are mediated by the appropriate hydrology because nutrients are dissolved or suspended in water that is being transported through the system at a rate and depth that optimizes interaction rates. Moreover, the underlying biogeochemisty functions best under a hydrologic scheme that more closely resembles the floodplain wetlands characteristic of the late 1800s rather than those of today's highly disturbed rivers. Consequently, a well-managed nutrient farm potentially provides better wildlife habitat and functions more similarly to a natural, undisturbed floodplain wetland.

One of the most important and beneficial aspects of a nutrient farm may pertain to its location. The most efficient farms will be built on an existing floodplain that has been disconnected from its river through a system of levees, ditches, and/or drainage. This disconnection has cost our society dearly in the quality of our water, catastrophic flood damages, and vastly diminished wildlife habitat. By reconnecting in a controlled manner, many of these losses can be restored. Much of the levee infrastructure can be readily converted to protect developing wetlands from the fluctuating water levels now characteristic of all major rivers due to land use changes throughout the watershed. Other locations include most areas along an impacted riparian corridor and the dead backwaters and floodplains of streams with steeper gradients.

Ecologists now recognize that functional natural systems are characterized by high levels of biodiversity and conversely that degraded systems are characterized by low biodiversity, a significant presence of invasive species, and reduced functional performance. However, the role of biodiversity in the efficient functioning of a nutrient farm is not well understood and is open to some debate. The role of biodiversity may depend upon the model on which the farm is based, such as a typical treatment wetland versus a biologically rich and heterogeneous wetland. Treatment wetlands are generally not diverse and are run under a homogenous set of conditions to maximize a single function (Kadlec and Knight 1996). For nutrient farming, we believe a biologically diverse wetland will provide a wider range of services and long-term performance at lower cost.

There is little doubt that biologically diverse systems share a number of characteristics that make them functionally superior to less diverse systems. Diverse systems are generally more productive, in that they produce more biomass per area annually

"It is critical that invasive species be managed if a nutrient farm is to function properly."

(Hooper et al. 2005). Diverse systems are more resistant to disturbance because events which impact or stress systems are less likely to result in significant damage or a lasting change in functional performance (Caldeira et al. 2005). Biologically diverse systems are also more resilient because once the system is perturbed, such as from a flood event, it will recover more quickly and reliably. This also makes diverse systems more stable and predictable, primarily because with greater species diversity they possess a wider range of functional attributes (Naeem and Li 1997; Sullivan et al. in publication). This is a type of ecological 'insurance', where the functional contribution of an impacted species may be replaced by the contribution of other species that are impacted to a lesser degree or not at all (Yachi and Loreau 1999).

Since nutrient farms are managed systems, developing and sustaining a biologically diverse plant, animal, and microbial community will require an active and strategic contribution to the ecosystem's dynamic processes. One of the most important of these elements is hydrologic management. Floodplain and marsh communities are adapted to flooding and drying cycles, with the highest levels of diversity and productivity developing under intermediate disturbance regimes (Huston 1994). Drawdowns and flooding events are critical for establishing and maintaining many wetland species (van der Valk 1981; Keddy 2000), with static conditions leading to losses in diversity and/or aggressive species invasions (Kennedy et al. 2002). Further research needs to be conducted to determine the relative importance of such events and the optimal duration and periodicity of their occurrence for the maintenance of an efficient nutrient farm.

One of the most significant challenges to the nutrient farmer will be managing the invasive plant and animal species. Invasive impacts are primarily due to the characteristics that define them as a group; they are early successional species that are very well adapted to disturbance events. In an environment where nearly all natural areas are continuously disturbed by human activities this makes them ideally suited for the invasion and displacement of native species. Invasive species may further enhance their advantage by altering their environment in a manner detrimental to desirable species. It is critical that invasive species be managed if a nutrient farm is to function properly. However, the tradeoffs inherent in any management scheme and the cost of invasive management relative to little or no management remain unknown for many species and circumstances. Invasive species management within the context of a nutrient farm is now an important research topic currently under investigation by TWI.

Another way that nutrient farms can contribute to biodiversity is the potential to restore and provide critical wildlife habitat. With the massive loss of wetlands throughout the Midwest, there have been dramatic declines in wetland-dependent species, many of which are economically and/or recreationally important (e.g. migratory waterfowl). Habitat loss not only affects all of the species that live in wetlands, but also a far larger number of species that rely on wetlands of one type or another for food, refuge, and/or reproduction, such as the Illinois State endangered Henslow's sparrow *(Ammodramus henslowii)*. Exacerbating wetland loss is the general degradation of what remains; nearly all remaining wetlands are fragmented, isolated, and impacted to some degree. Nutrient farms provide an opportunity to reverse these losses before many of the plants and animals dependent upon wetlands disappear locally or regionally. With relatively clean and clear water, the potentially large and biologically rich nutrient farm landscape can provide a resource that is virtually absent throughout the Midwest today; a wide range of habitat niche-space for many of the most rare, threatened, and endangered species throughout the region.

Conclusions and Recommendations

Pilot projects are needed to verify costs, scale-up considerations, and document nutrient removal rates so that nutrient farming will gain acceptance as a nutrient removal technology at a broad scale. TWI is developing a 1,300 acre nutrient farm pilot project along the Illinois River to demonstrate the ability of large-scale wetlands to achieve sustainable nutrient removal while restoring lost habitat and diversity. The success of this pilot project will allow Publicly Owned Treatment Works to take advantage of cost savings and maintain compliance to water quality standards. Nutrient farming provides a strategy that is more appealing than traditional wastewater treatment methods, which provide no additional benefits beyond nutrient reduction and are energy-intensive processes that rely on fossil fuels.

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Literature Cited

Caldeira, M.C., A. Hector, M. Loreau and J.S. Pereira. 2005. Species richness, temporal variability and resistance of biomass production in Mediterranean grassland. *Oikos* 110: 115-123.

Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, B.T. Aulenbach, R.P. Hooper, D.R. Keeney and G.J. Stensland. 1999. *Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the Integrated Assessment of Hypoxia in the Gulf of Mexico*. National Oceanic and Atmospheric Administration, Coastal Ocean Program.

Hey, D.L. 2002. Nitrogen Farming: Harvesting a different crop. *Restoration Ecology* 10(1): 1-10.

Hey, D.L., J.A. Kostel, A.P. Hurter and R.H. Kadlec. 2005b. *Comparing Economics of Nitrogen Farming with Traditional Removal*. WERF 03-WSM-6CO. Water and Environment Research Foundation, Alexandria, VA.

Hey, D.L., L.S. Urban and J.A. Kostel. 2005a. Nutrient farming: The business of environmental management. *Ecological Engineering* 24: 279-287.

Hooper, D.U., F.S. Chapin, J.J. Ewel, A. Hector, P.Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A.J. Symstad, J. Vandermeer and D.A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs* 75:3–35.

Huston, M. A. 1994. *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge University Press, Cambridge, England.

Kadlec, R.H. and R.L. Knight. 1996. *Treatment Wetlands*. CRC Lewis Publishers: New York.

Keddy, P. A. 2000. *Wetland Ecology: Principles and Conservation*. Cambridge University Press. Cambridge, England.

Kennedy, T.A., S. Naeem, K.M. Howe, J.M.H. Knops, D. Tilman and P. Reich. 2002. Biodiversity as a barrier to ecological invasion. *Nature* 417: 636-638.

Kostel, J.A., R.M. Peck, B. Scott and C. Tallarico. 2007. The Economics of Nutrient Farming – Draft Report. http://www.wetlands-initiative.org.

Mitsch, W.J. and J.W. Day, Jr. 2006. Restoration of wetlands in the Mississippi-Ohio-Missouri (MOM) River Basin: Experience and needed research. *Ecological Engineering* 26(1): 55-69.

Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall and N. Wang. 2001. Reducing Nitrogen Loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to Counter a Persistent Ecological Problem. *BioScience* 51(5): 373-388.

Naeem, S. and S. Li. 1997. Biodiversity enhances ecosystem reliability. *Nature* 390: 507-509.

Phipps, R.G. 1997. *Nitrate Removal Capacity of Wetlands*. Ph.D. Dissertation. Iowa State University, Ames, IA.

Sullivan, G., J.C. Callaway and J.B. Zedler. In publication. Plant assemblage performance explains and predicts complex responses of salt marsh ecosystems to plant biodiversity. *Ecological Mongographs*.

U.S. Environmental Protection Agency (U.S. EPA). 1995. *America's wetlands: Our vital link between land and water*. EPA 843-K-95-001. U.S. EPA Office of Wetlands, Oceans, and Watershed, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 2000. *Ambient Water Quality Criteria Recommendations (Information Supporting the Development of State and Tribal Nutrient Criteria): Rivers and Streams in Nutrient Ecoregion VI*. EPA 822-B-00-017. U.S. EPA Office of Water, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 2001. Nutrient Criteria Development. Notice of Ecoregional Nutrient Criteria. *Federal Register* 66(6): 1671-1674.

U.S. Environmental Protection Agency (U.S. EPA). 2004. *Water Quality Trading Assessment Handbook*. EPA 841-B-04-001. U.S. EPA Office of Water, Washington, D.C.

van der Valk, A.G. 1981. Succession in wetlands: A Gleasonian approach. *Ecology* 59: 322-335.

Walbridge, M.A. and J.P. Struthers. 1993. Phosphorus retention in non-tidal palustrine forested wetlands of the Mid-Atlantic region. *Wetlands* 13: 84-94.

Yachi, S. and M. Loreau. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proceedings of the National Academy of Sciences of the United States of America* 96: 1463-1468.

Zenz, D.R. 2003. *Technical Feasibility and Cost to Meet Nutrient Standards in the State of Illinois*. Report prepared for Illinois Association of Wastewater Agencies. Springfield, IL.

Fermilab: A Microcosm of Chicago Wilderness

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With a tradition of conservation, Fermilab is an example of how one consortium member applies restoration in action, as documented by Rod Walton

Fermilab's land management strategy centers on the steady addition of restored prairie over the last 32 years, resulting in approximately 1200 acres in 2006. In addition, the philosophy of stewardship at the Department of Energy Laboratory has evolved to include all other natural areas on the 6800 acre site. The organization incorporates strong elements of education, research and outreach in addition to managing the land. As such, Fermilab can be considered a model that reflects the structure of Chicago Wilderness as a whole.

History of Ecological Management at Fermilab

In the late 1960's, 6800 acres of Kane and DuPage counties were transformed by the U.S. Atomic Energy Commission (later the U.S. Department of Energy [DOE]), into the world's largest particle accelerator, originally called the National Accelerator Laboratory. The name was later changed to Fermi National Accelerator Laboratory, or Fermilab, in honor of Enrico Fermi. The accelerator itself, a complex of machines culminating in the four mile circumference "Tevatron", was built mostly underground, leaving an opportunity for some innovative land management on the surface.

In 1975, the Director of Fermilab, Dr. Robert Wilson, was persuaded by Dr. Robert Betz to begin a tallgrass prairie restoration in the center of the main ring. The initial effort consisted of only nine acres, but since that time additional acreage has been restored on a nearly annual basis. (Figure1)

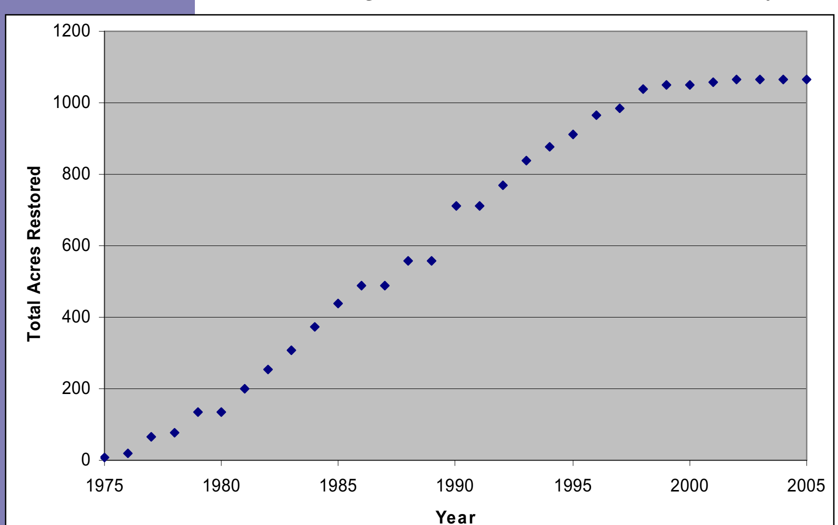

Figure 1. Cumulative acres of prairie restored at Fermilab from 1975 until 2005.

Currently, Fermilab boasts nearly 1200 acres of restored prairie. This undertaking was accomplished by volunteers, including employees from the Laboratory and from the surrounding communities. The Fermilab prairie is so extensive that new techniques modeled after large scale agricultural practices had to be devised.

Figure 2. A Fermilab groundskeeper loads a seed drill with prairie plant seeds in preparation for overseeding a prairie tract.

During the 1990's, the land management philosophy was expanded to include all the undeveloped areas of the Laboratory, and communities other than tallgrass prairie. The volunteer "Prairie Committee" became the "Ecological Land Management Committee" or simply ELM. As a result, the Laboratory manages the prairie restoration along with approximately 750 acres of open water and wetland, 700 acres of forests, 1200 acres of non-native grasslands, and 2000 acres of row crop agriculture. The remainder of the 6800 acre site is either industrial plant, civil construction, or turf grass.

The Fermilab Microcosm
Fermilab, like the Chicago Wilderness region, is thus composed of a mosaic of land uses. (Figure 3)

Figure 3. Land uses at Fermilab. ELM designations refer to the master plan for management, the ELM Plan.

This article argues that Fermilab, in its constitution and its approach to land management closely mirrors Chicago Wilderness in many ways. Therefore, Fermilab offers both a model and a laboratory for land managers in our region.

In its role as steward of the land on which it sits, Fermilab has relied heavily on volunteers. As the ELM Committee has matured, it has developed a set of objectives by which land management decisions are made. The official charter of the ELM Committee recognizes objectives that very closely resemble the objectives of Chicago Wilderness, articulated in the *Biodiversity Recovery Plan* (1999). (Table 1)

Fermilab ELM Charter Objectives	Chicago Wilderness BRP Objectives
• Reconstruct valuable ecosystems where possible and appropriate • Experiment with new and/or different land management techniques	• Protect, restore, and manage natural communities (Obj. 3, 4 & 5)
• Monitor and document the plant and animal life on site in order to track changes and asses the impact of management methods • Facilitate environmental research	• Manage with ecological principles (Obj. 2)
• Maintain or increase native biodiversity • Establish a biologically healthy distribution of community types	• Sustain and enhance biodiversity (Obj. 5)
• Provide a real asset for the use and enjoyment of the public	• Involve and educate citizens (Obj. 1 & 6) • Enhance quality of life for citizens (Obj. 8)
• Take appropriate measures to attain ecosystem sustainability	• Foster sustainable relationships between people and nature (Obj. 7)

Table 1. A comparison of Fermilab ELM Committee charter objectives with objectives from the Chicago Wilderness Biodiversity Recovery Plan

Our roles in research, education, and community involvement go beyond the traditional role of land management, and provide the most obvious correspondence with the larger mission of Chicago Wilderness. Fermilab thus offers "one stop shopping" for many of the roles that Chicago Wilderness espouses.

In the area of **environmental research**, Fermilab is home to one of only seven DOE-sponsored National Environmental Research Parks (NERPs). The parks are loosely associated through DOE. Fermilab's NERP is offered to environmental researchers as an outdoor laboratory for a wide array of investigations. Since the inception of the NERP in 1989, over 70 projects have been completed, ranging from very "low tech" observations to multi-million dollar studies. The prairie restoration program of adding acreage periodically has resulted in a "chronosequence" of restored prairie at various stages of succession that offers a unique snapshot of restoration succession dynamics. The diverse fauna offers many other opportunities to conduct research in a large and relatively secure ecosystem. Over 200 species of birds, and dozens of butterflies and skippers are regularly observed on the site and are typical of the biodiversity available at Fermilab.

Fermilab's commitment to **education** is exemplified by the Leon Lederman Science Education Center, which houses staff and resources used to support educational programs. Programs include on site field trips and programs aimed at ecology and prairie study for over 5000 students each year, and teacher workshops designed to give teachers the tools to create their own classes. A web-based Prairie Quadrat Study (http://ed.fnal.gov/programs/quadrat/) allows members of the public to actually participate in data collection in the study prairie on the Fermilab site. The Science Center also maintains an extensive Web site (http://ed.fnal.gov/entry_exhibits/main_title.html) concentrating on local ecology and designed to appeal to young students in grades from kindergarten through middle school. These activities are designed and administered by the Friends of Fermilab Science Education, a 501(c)(3) not-for-profit corporation, as well as by Fermilab itself.

Fermilab has abundant potential for **community involvement**. Unlike most other DOE complexes, Fermilab is a relatively open site allowing visitors to enter during working hours for various recreational, cultural and educational activities. Employees, physics researchers, and visitors take part in many volunteer efforts for restoration and maintenance of the site's environment. The program probably best known to visitors is the annual prairie seed harvest, which is conducted twice each Fall, usually in October and November. Hundreds of volunteers, armed with paper bags and garden shears, learn how to identify and harvest valuable seed from dozens of species for future use by the restoration effort.

A significant part of Fermilab's community involvement activities include outreach to other land managers in the area who are engaged in prairie restoration. Because of the scale of the Fermilab restoration and the techniques employed, large amounts of seed from more common prairie plants (e.g., tall grasses and larger forbs such as Silphium species) can be harvested each year. (Figure 4) This "prairie matrix" seed mixture is extremely valuable for the establishment of new prairie or maintenance of restorations during early succession. Fermilab donates matrix to 10 – 20 non-profit organizations each year for small restoration projects. We also exchange seed with organizations that actively manage their own restorations and harvest seeds. Typically, we can offer larger amounts of uncleaned matrix in exchange for small amounts of hand-collected seed from more conservative species. In these kinds of exchange, both Fermilab and the other organization benefit.

Figure 4. Using large farm machinery, Fermilab groundskeepers can harvest upwards of 20,000 pounds of "prairie matrix" seeds from mature prairie tracts each year.

Shared Problems

In addition to similar structures, objectives, and functions, Fermilab and Chicago Wilderness share many of the same problems, both ecological and organizational.

Groundskeepers and volunteers constantly experience the same challenges that others in the region face, such as invasive species, lack of budget, and limited resources. At Fermilab, as throughout the Chicago Wilderness region, restoration efforts come into conflict with building of roadways, residential and commercial development, and farmland. Fermilab is, above all else, a Laboratory devoted to high energy physics. The construction, operation, and maintenance of a large infrastructure to support an intensive physics research program inevitably competes with restoration efforts and maintenance of the site along more natural lines.

As a microcosm of the entire region, Fermilab planners face the same decisions regarding conflicting land usages that regional managers and planners face. Row crop agriculture, with its attendant energy- and chemical-intensive nature may not be what many of the more conservation-minded among us would like to see, but owing to limited budgets and resources, farming turns out to be a practical "interim" land management tool. Planning for the future of the Laboratory occasionally results in rejecting the restoration of a historic wetland or savanna area in favor of a planned new accelerator or support building.

These organizational decisions are dealt with constructively at Fermilab because of the cooperation between promoters of conservation, namely the ELM Committee, and the overall physics mission of the Laboratory. Similarly, Chicago Wilderness is an organization able to introduce conservation concepts into overall regional planning to effect realistic solutions acceptable to the greatest number of people.

The Future of Fermilab

As can be seen from the graph in Figure 1, the accumulation of restored acres of prairie at Fermilab has leveled off during the last five years. Given the current budget situation and resource allocation priorities, that is unlikely to change in the near future. The bulk of effort will thus be directed to maintenance and improvement of the acres that currently exist. The ELM Committee will, of course, continue to advise the Laboratory leadership on land management decisions and help to manage conflicts constructively. We intend to continue to reach out to others in the conservation and scientific communities to improve the quality of our work, and give others the benefit of our experience whenever possible. Most importantly, Fermilab will continue to learn.

Conclusion

The individual member organizations of the Chicago Wilderness consortium, perhaps especially the larger organizations that have more complex structures, can be seen as microcosms of the consortium itself. Fermilab is offered as an example, and I suggest that both as a model and experimental platform, Fermilab and presumably other CW member organizations can serve an important function for the leadership of Chicago Wilderness.

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Investigating the Reproductive Health of Hill's Thistle *(Cirsium hillii)* Populations in the Chicago Region

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Jeremie Fant, Susanne Masi, John M. Keller and Rebecca Mann investigate genetic diversity in an important native thistle.

Abstract
Hill's thistle *(Cirsium hillii)* is a native thistle that has a Priority 1 rating in Chicago Wilderness' *Biodiversity Recovery Plan*. Most populations of Hill's thistle in the Chicago Wilderness region produce few flowering stems and persist as basal rosettes, reproducing asexually via lateral roots. When flowers are produced, seed production is generally low. The combination of small, fragmented populations and low sexual reproduction increases the potential for inbreeding, which over time can lead to inbreeding depression. Consequently, we initiated the present study to examine genetic variation within six Chicago Wilderness Hill's thistle populations. We then compared these results to the genetic variation within five larger Hill's thistle populations which contained higher numbers of flowering individuals, and were therefore considered reproductively healthy populations. Using five years of monitoring data we found that the numbers of plants in the study areas fluctuated somewhat, but overall, most populations stayed relatively stable. Two populations showed a consistent decline due to the encroachment of woody invasive species. The genetic work confirmed that both sexual and asexual reproduction has played an important role in the creation of most of these populations. Populations persisting predominantly by asexual reproduction had very low genetic diversity, while those with higher levels of sexual reproduction had measures of genetic diversity comparable to the most prolific flowering population. These data suggest that low genetic diversity is not a problem in Chicago Wilderness Hill's thistle populations. There are significant gaps in knowledge of life history characteristics for this species, and further work is required to look at reproduction in order to explain the poor reproductive performance of plants in the Chicago region.

Introduction
Hill's thistle, *Cirsium hillii* (Asteraceae), is a northern native thistle, having been recorded in Minnesota, Wisconsin, Iowa, Illinois, Ohio, Indiana, western Pennsylvania, Michigan, and Ontario. Throughout its range, the species occupies upland, drained,

dry-mesic prairie with gravelly to sandy soil, or loam soils that possess at least some coarse element. Despite its wide distribution, Hill's thistle is listed as endangered in Indiana, threatened in Wisconsin and Canada, and a species of special concern in Minnesota and Michigan. Even in states where this species is not rare, most of its populations are small, fragmented, and at risk of local extinction, consequently in the Chicago Wilderness' *Biodiversity Recovery Plan* it was given it a Priority 1 rating.

Figure 1a Hill's thistle flower

Figure 1b Hill's thistle rosettes

Hill's thistle blooms from June through August (Figure 1a). As a perennial, it generally persists as basal rosettes, which after a number of years produce a flowering stem (Figure 1b). Although the flowering rosette will usually die after blooming, an individual plant will continue to produce new rosettes asexually via lateral roots. Seed production has generally been found to be poor in this species. McCann and Dannenhoffer (2002) found that in the open-pollinated group 37% of flowers produced seed, and only 7% in the self-pollinated group. Of those seeds that were produced, seeds from the open-pollinated plants had a mean germination of 62.4% compared to 9.4% in self-pollinated plants. This suggests that, although Hill's thistle is capable of self pollinations, it is highly susceptible to inbreeding depression.

One of the possible reasons for such low seed set could be due to a self-incompatibility system, which prevents pollen from related individuals from fertilizing the ovules and hence from forming seed. Another possibility for low seed set is inbreeding depression. One of the risks of small, fragmented populations is the increased likelihood of inbreeding, which over time can lead to inbreeding depression; a decrease in the average fitness of offspring. This ultimately accelerates the decline of that population. One sign of inbreeding depression is a reduction in reproductive success, which can be observed as a decline in floral production, fertility, and seed set.

Figure 2: Monitors searching for rosettes of Hill's thistle

As Hill's thistle is capable of reproducing by both vegetative and sexual means, it can be difficult to visually determine whether two rosettes are genetically distinct. Although two plants may be flowering within a population, if they are genetically identical a cross between these individuals is equivalent to self pollination. Molecular markers allow us to distinguish between vegetative and sexual growth and to quantify both the level of genetic diversity (maintained via sexual reproduction) within a population, as well as the degree of vegetative spread. In species that do reproduce asexually, molecular markers provide an important measure of genetic diversity and allow us to determine the effective population size, which counts the number of genetically distinct individuals rather than just the total number of plants.

We studied the genetic variation within six Chicago Wilderness Hill's thistle populations and compared this to larger and presumably reproductively healthy populations. With a better understanding of the levels and distribution of genetic diversity within these populations and their roles in reproductive success, we will be better able to guide management practices to ensure that population diversity is maintained at a healthy leve.

Methodology

Site Selection and Monitoring

Through the work of Chicago Botanic Garden's volunteer monitoring program, Plants of Concern, eight plots of Hill's thistle were monitored at six sites in the Chicago Region over six years (Figure 2). Plots did not always encompass the whole population at a site; hence a representative subset was selected, which we defined as a subpopulation of the larger population. Within the defined plots, 50-100 plants were tagged and followed for the full five years. At Sites 2 and 3 we established two separate plots, as Hill's thistle was found at two distinct locations at each site.

As this species can reproduce asexually, and as we found that original rosettes can move up to 20 cm from a central point from one year to the next, any rosette that was found within 20cm of a tag was considered part of the originally tagged plant, rather than a new plant. Each year, new plants more than 20cm from tags were considered new recruits, and were tagged and recorded. Plant size (rosette diameter), length of largest leaf, and number of rosettes was measured each year. If a flower was present, the stem length and number of flower was also recorded. In addition, land owners and monitors were asked to describe site management practices undertaken between the monitored years (Table 1).

	Site 1	Site 2 Plot 1	Site 2 Plot 2	Site 3 North	Site 3 South	Site 4	Site 5	Site 6
2001						Burn	Mow	Burn
2002		Invasive removal	Invasive removal			Mow	Mow	Burn-Invasive removal
2003	Invasive removal	Burn	Burn	Burn	Burn	Mow		Burn
2004	Mow/Invasive removal	Burn	Burn			Burn		Burn
2005	Burn	Invasive removal	Invasive removal			Invasive removal		Burn
2006								

Table 1 Management practices by site and year

Seed Production Study

In 2004, five of seven Hill's thistle monitored sites had flowering plants, which were examined for production of viable fruit. All plants produced only single flowering heads with the exception of Site 4, where plants produced between two and 12 heads each. Once natural pollination had occurred, approximately one week after opening, all flower heads were enclosed with a nylon mesh bag. After a two to three week period, when the seed had matured within the bag as indicated by the abscission of seed from head and graying of pappus, the heads were removed from the plants and brought back to the laboratory for analysis. Seed viability was initially determined using a cut test: seeds were cut in half and any seed that was plump and full with an embryo and endosperm was counted as viable (Figure 3a, b). We then learned that a simple depression test could be used to determine viability without destroying the material. Seeds were depressed with a lab tool; all full, non-collapsing seeds were assumed viable. Seeds determined to be full via the press test were also weighed. Seed weights ranged from 0.003g - 0.0095g. If a seed weighed less than 0.004g, it was re-examined for fullness using the cut or press test. Average seed weights, and percent seed viability per head were calculated. All flower material was returned to the original site.

Figure 3a

Figure 3b

Genetic Study

To compare genetic differences between populations, leaf samples were collected from 30-40 individuals at each site in 2004 for genetic fingerprinting. Microsatellite markers developed for other Cirsium species (Jump et al. 2002) were screened on Hill's thistle, and five primers were identified which worked well on this species. We have to-date screened most plants collected from each site with all five of these markers, generating a "fingerprint" or genotype for each individual tagged plant. This allows us to compare fingerprints for each individual, and say with some confidence that plants with the same fingerprint are likely from the same source (i.e. vegetative reproduction), and those that differ are derived from seed (i.e. sexual reproduction).

To compare differences between populations, we used one representative from each monitored tag at each site. However, to address the question of whether multiple rosettes found near a single tag are derived from a single plant or multiple plants, we genotyped all rosettes at a number of tags (Table 2) using the five microsatellite markers outlined above.

Table 2: The average number of genetically distinct individuals (genotypes)

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
# tags sampled	2	9	3	5	4	1
# rosettes per tag	5	2-4	2-4	3-5	2-4	2

With this comparison between number of genotypes (G) and number of plants (N), we can calculate G/N as a measure of the ratio of sexual reproduction. Other measures of genetic diversity include number of variants recorded for each marker (polymorphisms per locus) and gene diversity, a measure of the probability of a gene varying at each site studied.

Comparisons

Knowing the range of genetic variation within Hill's thistle populations in the Chicago Wilderness region allows us to identify populations that are low in genetic diversity, but it does not tell us which, if any, of the study populations have "sufficient" genetic diversity. To do this, it is necessary to locate populations considered to be reproductively healthy, and determine the level of genetic diversity in these populations as points for comparison. For this, we traveled to sites at the perimeter of the Chicago Region with relatively large populations of Hill's thistle containing many flowering individuals. The actual number of individuals in these comparison populations was not counted, but landholders and managers indicated that there were over 100 plants at each site. However, the number of flowering individuals was recorded at each site. The largest population by far was WI-1, in Wisconsin, which had over 100 individuals flowering. This was followed by IL-1, in Illinois, and WI-2, in Wisconsin, which had close to 50 flowering individuals. These numbers suggest that these populations are likely to be sexually healthy, reproducing populations. Two other populations (IL-2 and WI-3) have not flowered in a number of years, but were added for comparative purposes. WI-3 has been monitored by the Department of Natural Resources in Wisconsin and we are hoping to combine data sets to increase the sample size for future publication.

Genetic Structure

In the Midwest, the gravel-hill habitat on which Hill's thistle grows is fragmented and rarely extensive. This can have an important effect on the genetic structure of populations occupying this fragmented habitat. In plants that have an extensive range, or long distance pollen or seed dispersal, gene flow can occur over wide distances. In these cases, gene flow will frequently occur between populations and therefore the genetic distance (differences) between populations will be small. In fragmented populations, gene flow can be restricted. In these situations, the genetic distance, and hence differences, between populations can be quite large. By comparing the genetic distance between populations within the Chicago Region, we can determine how isolated these populations are to each other. The smaller the genetic distance, the more closely related the populations are. In isolated populations, genetic distances may be small if pollen or seed moves between the populations, or if the two populations were historically part of one larger population which has subsequently been fragmented.

Table 3: Number of plants in monitoring area by site, year, and burn treatment. (Change from previous year in parentheses; years and sites that were burned are bolded.)

Year	Site 1	Site 2a	Site 2b	Site 3a	Site 3b	Site 4	Site 5	Site 6
2001	57						50	
2002		75	27	12	30	70	43 (-7)	**21**
2003	80 (23)	**111 (36)**	**38 (11)**	**18 (6)**	**72 (42)**	79 (9)	43 (0)	**23 (2)**
2004	87 (7)	**132 (21)**	**60 (22) ***	16 (-2)	68 (-4)	**102 (23)**	48 (5)	**27 (4)**
2005	**89 (2)**	144 (12)	68 (8)	17 (1)	65 (-3)	94 (-8)	44 (-4)	**26 (-1)**
2006	63 (-26)	146 (2)	64 (-4)	14 (-3)	79 (14)	74 (-20)	23 (-21)	**23 (-3)**
Area Monitored	25 m2	55 m2	18 m2	12 m2	65 m2	30 m2	25 m2	**16 m2**

* The large jump was in part due to plants outside plot area also being tagged.

	Site 1	Site 2a	Site 2b	Site 3a	Site 3b	Site 4	Site 5	Site 6
Average Size (Diameter in cm)	22.67	19.34	18.83	25.25	27.62	25.94	16.70	23.20
Rosettes Per Tag	1.12	1.29	1.42	1.15	1.16	1.25	0.84	0.94
Average Density (rosettes per m2)	3.2	2.4	2.5	1.4	1.2	2.8	1.7	1.6

Table 4: Average size, number of rosettes per tag and average density of rosettes by population

Results and Discussion

Monitoring

For most populations, and subpopulations, the number of plants in each study area fluctuated somewhat over five years, but overall most stayed relatively stable (Table 3). Importantly, the monitored populations at Sites 1 and 5 are both declining, most likely due to the encroachment of woody invasive species. It should be noted that, at these sites, plants seem to be moving outside the monitored plot to avoid the shading effects of these invaders. Interestingly, the largest increases in numbers were found in years when populations were burned.

Plant size (rosette diameter) and number of rosettes can be used to gauge the health of individual plants at each population over all monitoring years (Table 4). While these measures of health varied by both year and population, variation by year was linked to local weather conditions and site management, with plants being smaller during drier years and larger after burns. Not surprisingly, there was an inverse relationship between average number of rosettes per plant and plant size; plants that reproduced asexually tended to have smaller rosette diameters. The choice between investment in plant size versus vegetative reproduction is likely related to plant densities, interspecific competition and local growing conditions, including characteristics such as nutrient levels, slope, and aspect. Site 2 had smaller plants with more rosettes, and therefore it is not surprising that this site also had some of the highest densities of rosettes. Site 3 and Site 6 had larger plants, fewer rosettes per plant, and some of the lowest plant densities. Site 5 was an outlier, as it had smaller plants, fewer rosettes per plant, and low densities of plants, further highlighting the decline in this subpopulation. Site 1 had very high plant density with relatively large plants, although a low number of rosettes per plant. This population appears to be shifting to fewer rosettes and larger plants, with density declining rapidly (results not shown). Site 4 was also interesting in having a relatively high number of rosettes per plant and big plants. These plants are growing in high quality gravel hill habitat with shorter associated grasses and forbs and, hence, probably lower competition for light and resources.

Reproductive health of Chicago Wilderness populations
The primary concern, however, for all monitored populations has been the lack of flowering individuals and when plants do flower, the low seed set recorded. Flowering in the monitored Hill's thistle populations varied, with some sites never producing flowering plants, while others had at least one plant blooming every year. Within a single population, there was considerable variation in the number of tagged plants that flowered, ranging from 21% (17 plants) in 2003 at Site 4, to only a single plant in many populations (Table 4). The differences in flowering seem likely to be due to a combination of management practices, with fewer flowers in burn years, and seasonal conditions; in particular, the dry spring of 2005 saw few plants flower. However, the negative effects of low flowering are compounded by the low recorded seed set in the few plants that do flower (Table 5).

	Site 1	Site 2a	Site 2b	Site 3a	Site 3b	Site 4	Site 5	Site 6
2001								
2002		6.7% (5)	19% (5)	8.3% (1)	3.3% (1)	30% (21)	16% (7)	BURN
2003	1.3% (1)	**4.5% (5)**	BURN	BURN	BURN	21%(17)	2.3% (1)	BURN
2004		**3% (4)**	**10% (6)**		5.9% (5)	**7.3% (5)**	6.3 % (3)	BURN
2005	BURN		1.5% (1)		1.5% (1)	3% (3)		BURN
2006	3.1% (2)	1.4% (2)			1.3% (1)	1.4% (1)		BURN

Table 5: Percent of tagged individuals that flowered (total number of flowering plants in parentheses; years and sites which were burned are in bold font if they flowered or indicated as such)

Site	Site 1	Site 2a	Site 2b	Site 3a	Site 3b	Site 4	Site 5	Site 6
Total # Plants in Plot*		132	60		68	102	48	
# Plants Flowering		4	6		5	5	3	
% Plants Flowering		3.0%	10.0%		5.9%	7.3%	6.3%	
Mean # Seed per Flower Head		174	67		80	164	125	
% Seed Assumed Viable		16.9%	6.0%		0%	10.9%	24.2%	
Mean Seed Weight		0.0055	0.0049		n/a	0.0058	0.0053	
Total # Seed Developed at Site		113	3		0	484	119	

Table 6: Summary of seed production results in 2004

Seed Production Study
In 2004 only five of the eight study plots produced flowering plants (Table 6). Harvested heads produced between 28 and 343 seeds each. Percent viable seed per head ranged from 0% to 48%. No significant differences were found between the number of seed per head at each site or between the percent of viable seed per site. Seed weights were found to be significantly different at each site ($P < 0.0001$). Site 2b, with only three seeds, was not included in these statistics.

Clonal Growth
Using molecular markers, we genotyped all the rosettes at a number of tags and found that, in most cases, all rosettes were identical, hence likely derived from vegetative growth and therefore all offshoots of the same plant. Exceptions came from Sites 2 (both plots) and 4, where many of the rosettes around individual tags were different genotypes. This is not surprising, given that these populations had some of the highest plant densities, increasing the likelihood that two genetically distinct plants are growing in close proximity.

Another concern with Hill's thistle has been that the entire population could possibly be comprised of a single clone. With this research, we demonstrated that all sites had multiple genotypes (G), suggesting that sexual reproduction has occurred in the past (Table 5). That said, a number of populations have very few genotypes, particularly Sites 1 and 6. Consequently, the measure of sexual reproduction (G/N) was low. For example, Site 1 had a G/N of 0.1, meaning that only one in 10 individuals in the population was derived from sexual reproduction, while nine in 10 were from vegetative growth. In other populations, like Sites 2 and 4, the G/N ratio was much higher, with as many as four in ten individuals derived via sexual means. This is not surprising, as both of these populations typically have the greatest number of flowering individuals, whereas Sites 1 and 6 rarely have any.

Genetic diversity
Although the number of clones in a population is a good measure of how often plants may sexually reproduce, it is not a good indicator of genetic diversity within a population. A single clone could flower each year but this would not introduce any new diversity to a population. Other measures used include, number of variants recorded for each marker (polymorphisms per locus), this tells us a proportion of total variation can be found within and population and gene diversity, a measure of the probability of a gene varying at each site measured. Combined with measures of clonal growth, these two additional methods of counting variation within a population give us a more complete picture on the genetic diversity within a population. Not surprisingly Sites 2 and 4 had the highest diversity for both measures, while Site 6 had the least. Interestingly, Site 1 had only a few genotypes, yet contained higher levels of diversity than Site 6.

Is this sufficient genetic diversity?
In comparing measures of diversity between the designated "healthy" populations with those found for the smaller Chicago Wilderness populations, we see that all populations are very similar (Table 7). The measure of sexual reproduction was between 0.2-0.23 for most populations (i.e., roughly two in ten individuals resulted from sexual reproduction). The value for the healthy WI-1 population was much higher, but this is likely due to samples being collected from over a larger distance, and therefore less likely to have arisen from lateral roots. The values for polymorphisms per locus and gene diversity for these sites were also very similar to

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	WI-1 (WI)	WI-2 (WI)	IL-1 (IL)	IL-2 (IL)	WI-3 (WI)
No. of flowers (2006)	2	2	1	1	0	0	100+	33+	50+	0	0
No. of tagged plants sampled (N)	40	43	38	48	38	25	40	30	40	40	30
No of genotypes (G)	4	20	10	20	9	4	22	7	9	9	6
Sexual reproduction (G/N)	0.1	0.45	0.26	0.42	0.23	0.16	0.55	0.23	0.22	0.22	0.2
Average No. of polymorphism / locus	2.5	4.4	2.9	4.5	3	1.5	3.75	2.75	2.5	2.25	2.5
Gene diversity	0.43	0.65	0.52	0.63	0.28	0.14	0.65	0.52	0.45	0.34	0.38

Table 7: Genetic data from Chicago Wilderness populations

	Site 1	Site 2a	Site 2b	Site 3a	Site 3b	Site 4	Site 5	Site 6
Site 1								
Site 2a	0.22							
Site 2b	0.22	**0.07**						
Site 3a	0.39	0.19	**0.07**					
Site 3b	0.26	0.15	**0.10**	**0.10**				
Site 4	0.20	**0.07**	**0.05**	0.14	0.14			
Site 5	0.43	0.28	0.32	0.39	0.25	0.27		
Site 6	0.44	0.37	0.41	0.54	0.28	0.37	0.49	

Table 8: Genetic distances between Chicago Wilderness populations. The larger the number, the greater the genetic distance. Values under 0.1 are bolded and suggest less isolation, and therefore similar, populations.

what we found for Chicago Wilderness populations; Sites 2 and 4 have similar numbers to the healthiest population, WI-1.

Genetic differences

As genetic differences are calculated using gene frequencies, the values for Hill's thistle populations will be somewhat skewed due to the presence of clones within the populations. Nonetheless, trends are readily apparent. Not surprisingly, the subpopulations within each site are genetically similar, as there is likely gene flow occurring over such small distances (Table 8). Interestingly, we see that Sites 2 and 4 are not that isolated from each other, but this result may be explained by their proximity to each other. Sites 1, 5, and 6 are genetically distant from all other populations. This is likely a consequence of the high number of genetic clones within these sites, which has skewed their values to appear more genetically distant than they are.

A comparison of genetic distances between Chicago Wilderness populations and populations in Western Illinois and Wisconsin revealed even higher genetic distances (data not shown). This would suggest that Hill's thistle populations in the Chicago Wilderness region are genetically unique, and unlike other neighboring populations.

Conclusions/Recommendations/Implications

Through our monitoring efforts we found that in most populations, the numbers of plants in the study area fluctuated somewhat, but overall most stayed relatively stable (Table 1). Two populations did show a gradual decline in numbers, which can be attributed to the encroachment of woody invasive species. The largest increases in numbers were found in years when populations were burned. Flowering in the monitored Hill's thistle populations varied, with some sites never producing flowering plants, while others having at least one plant blooming every year. The differences in flowering within a site seem likely due to a combination of management practices and seasonal conditions.

Seed set in all populations was low, with less than 20% developed seed being produced. Genetic work confirmed that both sexual and asexual reproduction played an important role in the creation of most of these populations, the relative proportions of which varied by population. This was reflected in the measures of genetic diversity, with populations persisting predominantly by asexual reproduction having very low genetic diversity, while those with apparently higher levels of sexual reproduction having measures of genetic diversity as high as the largest and most prolific flowering population we could locate (100 plus flowering plants). These data suggest that low genetic diversity is not a problem in the Chicago Wilderness area. Additionally, comparisons to populations outside the Chicago Region revealed that our monitored populations are genetically unique. Given the levels of genetic diversity in some Chicago Wilderness populations, it appears that inbreeding depression is not the likely cause for the poor reproductive success in these populations. That said, we do not have any monitoring data from larger comparison populations, and so cannot confirm that they produce more viable seed and are truly healthy, sexually reproducing populations. If these large populations also suffer from the same problem of poor seed set as in the Chicago Wilderness region, then inbreeding depression becomes a much more likely cause of poor reproductive success. It seems likely that more flowering individuals in a population lead to a higher likelihood of reproductive fitness. Given this, more work is required to determine flowering cues within this species, and what role management practices play. Preliminary data suggest that burning increases plant size, most likely due to reduced competition and higher resource availability to allocate to growth. However, this might be at the expense of flowering. It is clear that there are significant gaps in knowledge of the life history characteristics for this species, and that further work is required to look at reproduction in order to explain the poor performance of these plants in the Chicago region.

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References

Jump, A.S., Dawson, D.A., James, C.M, Woodward, F.I. and Burke, T. 2002. Isolation of polymorphic microsatellite in the stemless thistle (Cirsium acaule) and their utility in other Cirsium species. Molecular Ecology Notes 2: 589-592.

McCann, K. and Dannenhoffer J.M. 2002. The reproductive biology of Hill's thistle, Cirsium hillii. Botany Conference 2002 Ecological Section. Madison, Wisconsin

Book Review

The Chicago River: An Illustrated History and Guide to the River and Its Waterways (Second Edition)

David M. Solzman
The University of Chicago Press, 2006
Reviewed by Cathy Jean Maloney

The recently released second edition of David Solzman's book, *The Chicago River,* clearly shows how fluid and resilient this wonderful waterway is. Reprinted just eight years after its first release in 1998, *The Chicago River* fine-tunes well-known lore about the river, and updates readers on recent progress in regions of the extensive watershed such as the Calumet River and the old U. S. Steel South Works property.

Solzman begins his book with Section 1; a solid underpinning of the geography of Chicago's waterways. From the glacial formation of the short-lived Lake Chicago through the creation of upland moraines and lesser lakes, Solzman primes the canvas of our current landscape. This section is generously enhanced with line drawings and black and white photographs, as is the whole book. Sidebars and factoids add interest without distraction. (Did you know, for example, that remnants of Lake Chicago include Wolf Lake, Hyde Lake, and Lake George?)

It soon becomes apparent that while the Chicago River is the star of this book, many other waterways are major players. Also described are the Chicago River's tributaries, branches, and canals, for example; the Skokie River and Skokie Lagoons, the North Shore Channel, North Branch Canal, South Branch, South Fork, Sanitary and Ship Canal, and adjacent waterways such as the Grand Calumet River, Little Calumet River, and Cal-Sag Channel. The different historical uses of the waterways—and their changing effects on the flora and fauna of the surrounding land, are described in a clear, engaging narrative.

As technology and industry evolved from explorers' canoes to barges on the Illinois & Michigan canal, manmade changes were made to the Chicago River and its tributaries. Most renowned, perhaps, is the much-ballyhooed 1900 reversal of the river's flow to improve sanitary conditions. But equally important both to commercial and environmental impacts were the widening of the river harbor, the cutting of various canals, and channeling of the river. Solzman begins with the

Chicago River in its natural state, and through historical progress develops overlays of the much different waterways that we know today.

Section 2 of the book offers a so-called "circle tour" of the Chicago River and its related waterways. Nearly every member of Chicago Wilderness is affected—from the Chicago Botanic Garden near the Skokie River southward to Hegewisch near the Calumet River. Along the way Solzman pulls out interesting anecdotes such as the effectiveness of Sidestream Elevated Pool Aeration (SEPA) stations in cleaning up the Calumet, the improved North Shore Channel thanks to the Deep Tunnel project, and other environmental success projects. Documented accounts of returning wildlife are used to bolster his examples.

A list of organizations—many of them Chicago Wilderness members—involved in assuring the quality of the Chicago River and its watershed is included in an appendix. Along with a useful index and at-a-glance Chicago River and Waterways timeline, this book offers a quick reference for those with an immediate need-to-know. But readers will want to spend a bit of time studying the charts and line drawings, and rereading chapters to truly appreciate how our Chicago River was and is our lifeline to the world.

Cathy Jean Maloney is on the Board of Directors of the Prairie Club, and can be contacted through prairieclub@sbcglobal.net.

Web Review

Web Resources for Global Climate Change

Robert G. Sullivan
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Global climate change (GCC) represents a serious threat to biodiversity, and is felt by some to be the greatest environmental threat that humanity has faced to date. These days global climate change is a hot topic in the media, and the Internet is no exception; literally hundreds of articles about GCC appear on the Internet each day. A rapidly growing number of Web sites discuss particular aspects of GCC, but often are directed at researchers or policy makers. Relatively few sites cover GCC broadly and thoroughly, yet are written for non-experts. There is a pressing need for more Internet-based sources of basic information on GCC that go beyond simplistic descriptions of the greenhouse effect and a list of “things you can do” to combat global warming. This review will cover two web sites that are good general sources for GCC information and suitable for beginners looking for a more thorough treatment of this important topic. Additional resources for those interested in further exploration of the topic are will also be covered briefly.

Pew Center on Global Climate Change
http://www.pewclimate.org/
According to their Web site, the Pew Center on Global Climate Change (established in 1998) is a non-profit, non-partisan, and independent organization that provides “credible information, straight answers, and innovative solutions in the effort to address global climate change.” The Center purports to bring together “business leaders, policy makers, scientists, and other experts” to address the complex issues associated with GCC, and provides a wealth of information for all these groups as well as the general public. While the site provides good basic information on GCC, the real “gold mine” is the large number of Pew reports available through the site. The reports cover nearly every major topic related to GCC, and are generally well-written, relevant, and useful to both understanding the facts of GCC and identifying the path forward for the U.S. to combat the growing GCC problem.

The Pew Center Web site is divided into five major GCC topic areas: *Global Warming Basics, Global Warming in Depth, Policy Center, Businesses Leading the Way*, and *What's Being Done*. There is also a Press Room section, a Publications page, and the typical About Us section.

The *Global Warming Basics* section provides a very good overview of the science behind GCC, the main effects of GCC on the environment and society, and current efforts to combat global warming. The section includes a series of well-written GCC fact sheets (under "*Climate Change 101*"), links to a number of longer Pew science reports (under "*Basic Science*") a well-organized *Frequently Asked Questions* (FAQ) page, a basic GCC glossary, and a Facts and Figures section that presents graphs, charts, and other illustrations that highlight important GCC concepts and findings; there is also an *Online Resources* page, but it is weaker than the other pages in this section. Throughout the *Global Warming Basics* section, the emphasis is on "plain-English" explanations that are easy to understand without being simplistic. It's an excellent starting point for learning about GCC.

Global Warming in Depth primarily serves as an organizational framework for links to numerous Pew Center reports covering GCC economics, environmental impacts, GCC "solutions" (including international efforts), policy issues, business initiatives and GCC workshops and conferences. The report links are useful, but the content on the Web pages themselves is thin for some of these topic areas.

Like *Global Warming in Depth*, the *Policy Center* serves primarily as a "front end" to Pew Center policy analyses, reports, and Congressional testimony, but there is such a wealth of policy-related information on the site that the Web front end provides a very useful organizational framework. In addition to U.S policy issues, the site provides subsections devoted to state and international policy issues, with the international policy section the stronger of the two.

Businesses Leading the Way highlights the GCC-related accomplishments of the Pew Center's Business Environmental Leadership Council (BELC). BELC members include major international corporations such as GE, IBM, and Royal Dutch/Shell that have initiated programs to reduce greenhouse gas emissions and/or undertaken other GCC-related initiatives.

What's Being Done highlights GCC solutions at the global and state levels, as well as congressional GCC-related initiatives and activities, and business activities. The treatment is uneven; the state solutions page provides rich resources and in-depth coverage, while the business solutions subsection simply links to the *Business Leading the Way* section, and the *Individual Action* page is a disappointment.

Although the Pew Center Web site does not explicitly address impacts of GCC on biodiversity, entering the term "biodiversity" into the site's search tool generates 116 returns, many of them Pew reports that deal with biodiversity and related issues, such as sustainability.

Despite some weaknesses, overall the Pew Center on Global Climate Change is a very good resource for both basic and in-depth coverage of GCC topics, with a wealth of good information residing in the many Pew reports available through the site. CW members and others should find it well worth a visit.

Environmental Protection Agency: Climate Change
http://www.epa.gov/climatechange/index.html
The U.S. Environmental Protection Agency has a substantial Web site devoted to GCC, with the detailed structure laid out as links on the home page, a useful feature. As with the Pew Center site, there is a great deal of both basic and detailed GCC information; however, more of the EPA site's content is actually on the Web pages rather than being found in linked PDF-based reports. The topic treatment is generally more consistent on the EPA site than on the Pew Center site, and more thorough, especially with respect to scientific content. Like the Pew Center site, the content is generally well-written, and targeted to a non-technical audience, hence it is also a good starting point for persons looking for a solid understanding of the basics of GCC.

The EPA site is divided into five main topic areas: *Basic Information, Science, Greenhouse Gas Emissions, Health and Environmental Effects, U.S. Climate Policy*, and What *You Can Do*. There is also an "Other Resources" section, as well as a Glossary, a detailed "Climate Change: Kids' Site" and several other minor utilities and resources.

The *Basic Information* page introduces basic GCC topics while serving as a gateway to the other main sections of the site. The *Science* section provides information and data on climate change in the distant past, the recent past, and projections for the future. It examines the nature and causes of climate change, and discusses some methods by which climate change is detected, assessed, and predicted.

The *Greenhouse Gas Emissions* section provides detailed information about the various greenhouse gases that contribute to GCC, and discusses inventory levels of these gases in the U.S. and elsewhere, as well as forecasted trends in greenhouse gas emission. Links to sites for calculating greenhouse gas emissions for individuals are provided as well.

The *Health and Environmental Effects* section provides much information about the effects of GCC on health, agriculture, energy production, and the environment, including a page devoted to effects on ecosystems and biodiversity. Along with basic information, this page includes links to several reports of interest. GCC effects are also examined across regions, including coastal areas, polar regions, and U.S. regions.

U.S. Climate Policy presents information on a wide variety of Federal programs relating to global climate change science, reduction of greenhouse gases, clean energy technology, and international cooperation. Like all sections of the site, numerous off-site links are provided.

What You Can Do provides numerous tips for energy conservation and greenhouse gas reduction at home, at the office, on the road, and at school, as well as information on waste generation and greenhouse gas production and management of agricultural and forested lands. The pages have links to other resources, including several online tools for estimating your own greenhouse gas emissions.

Other resources on the EPA Climate Change site include: a glossary; a "Climate Change Kids Site" that has a wide variety of information, games and animations, and also information for educators; a "Where You Live" section highlighting program sin your area, and a "Related Links Directory" featuring 250 Web resources for global climate change.

Overall, the EPA site is a comprehensive and well-organized resource for persons learning about global climate change. It's a great starting point for most beginners, but with plenty of links to more in-depth resources.

Additional Resources

United Nations Intergovernmental Panel on Global Climate Change (IPCC)
http://www.ipcc.ch/
The World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988, and the IPCC is regarded by many as the world authority on global climate change. The recent IPCC report "The Physical Basis for Global Climate Change: Summary for Policy Makers" received massive media coverage. The IPCC Web site does not contain a basic science section, but does have links to numerous important IPCC reports on global climate change. A science background is needed for understanding many of the reports, although the summaries are generally written for non-scientists.

U.S. DOE Energy Information Administration
http://www.eia.doe.gov/
A key to understanding the global climate change problem is to understand how energy is produced and consumed. The Energy Information Administration (EIA) is a statistical agency of the U.S. Department of Energy, and is the keeper of much important energy-related data for the U.S. government. Amongst statistical reports on all things energy, the EIA web site has a good "Energy Basics 101" section that explains the basics of all major sources of energy used in the U.S., and by extension the world. Included is an "Energy Kid's" page (really a multi-page section) that contains a wealth of energy information, including energy saving tips, classroom activities, energy news, puzzles, and games. The "Forecasts and Analysis" section provides very important reports that contain short- and long-term projections global and U.S. energy production and consumption, including forecasts for greenhouse gas production. The "Environment" section is focused primarily on global climate change concerns, but the emphasis is on presenting data (e.g. annual U.S. carbon emissions) rather than explanatory information.

Natural Resources Defense Council (NRDC)
http://www.nrdc.org/globalWarming/default.asp
The NRDC Web site has a "Global Warming: In Brief" section that provides links to a somewhat eclectic collection of essays, fact sheets, guides, and other non-technical resources on global climate change. The "Global Warning: In Depth" section links to reports, policy and technical analyses, testimony, and other materials from NRDC's lawyers, scientists and analysts. The "Related Links" page has a short list of high quality links to global climate change Web resources with link descriptions.

Nature Conservancy: Climate Change and Global Warming
http://www.nature.org/initiatives/climatechange/
As one would expect, The Nature Conservancy is concerned about, and taking action on, global warming. Their work is highlighted under the "Conservation Initiatives" section of The Nature Conservancy Web site, and includes some basic information

on global climate change, especially impacts of climate change. Also included are "climate-saving" tips, and a global climate change quiz.

An Inconvenient Truth
http://www.climatecrisis.net
While Al Gore's documentary "An Inconvenient Truth" provides much good basic information on global climate change in a compelling format, the Web site associated with "An Inconvenient Truth" has information of value beyond discussing/advertising the movie, including educators' resources, RSS feeds with news and events related to global climate change, and a good "Take Action" page. The "Take Action" page features a personal impact calculator that calculates your carbon emissions, several pages of tips for reducing emissions, and suggestions for becoming politically active.

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Chicago Wilderness Journal Guidelines to Authors

Do you have important research or a great success story that you believe your Chicago Wilderness colleagues would find interesting and useful? These guidelines explain what we're looking for and how to submit an article.

About the *Chicago Wilderness Journal*

Mission of the *Chicago Wilderness Journal*:

1. Facilitate the sharing of results and lessons learned from member-initiated projects and activities, including consortium-funded projects, team activities or the work of individual member organizations that would be useful to the wider membership;
2. Through easily consumable articles discuss practical implications, interpret data, and/or make recommendations about issues within the areas of science, land management, sustainability, education, and communication in the Chicago region;
3. Foster a sense of community among Chicago Wilderness members and improve members' ability to communicate with diverse audiences.

This journal is:

- A forum for sharing important results and lessons learned through biodiversity conservation work,
- An interdisciplinary publication that features a mix of articles in each issue from the fields of science, land management, education, communication, and sustainability,
- An online journal, published three times a year, guided by an editorial board made up of Chicago Wilderness members and consortium staff.

This journal is not:

- A peer-reviewed journal,
- A forum of advocacy or political positions,
- A newsletter with event announcements,
- A means of presenting biodiversity issues to the general public.

What we're looking for in an article

Submissions will be considered from the volunteers and employees of Chicago Wilderness member organizations, and from participants in Chicago Wilderness Teams and projects. Articles should report on the results of a Chicago Wilderness project, workshop, roundtable, or the results of such work performed by an individual Chicago Wilderness member organization. While the emphasis of this publication is on Chicago Wilderness members and affiliates, submittals from outside the membership that are relevant to the Chicago Wilderness audience will also be considered. The topic should pertain to biodiversity conservation in this region. Articles should emphasize the lessons learned and interpretation of data, rather than methodology or simply reporting of results.

Questions to answer in the article include:
- Why did you undertake the project and what did you do?
- What did you learn from the experience? What do your results tell you?
- What are the practical or applied implications of the work—both in your field and in other fields?
- Based on what you learned what do you recommend to Chicago Wilderness members?

Note that articles don't necessarily need to tell a success story; if valuable lessons were learned from an unsuccessful project, please consider submitting an article.

Target audience

The target audience for this journal is the volunteers and employees of Chicago Wilderness member organizations, and participants in Chicago Wilderness Teams and projects. To meet the needs of this broad audience, articles should:
- Emphasize practical implications,
- Be easy to read and interesting, not overly technical and full of jargon,
- Be short but refer to additional sources of information for interested readers,
- Help readers feel connected to other Chicago Wilderness members,
- Offer readers information and resources that will help them carry out their jobs.

Article format

Please submit your article as a Microsoft Word or WordPerfect file. Articles should be three to five pages in length (approximately 450 words per page). Pictures and graphics are welcome and encouraged, but the editorial staff will make final selections! Graphics files can be submitted at 72 dpi, actual size or larger. JPG files are the preferred format for graphics. The journal can accommodate sidebars, so please indicate if there are quotes or charts that you would like set out from your article.

All articles must include the following components:
- A short abstract of several sentences that will quickly capture the reader's attention,
- A description of the work you did and why you did it,
- Results and implications for Chicago Wilderness partners.

Beyond these requirements, articles may follow a variety of outlines as suggested by these examples:

Traditional scientific research format:
- Abstract
- Objectives
- Methods
- Results and Discussion
- Conclusion/Recommendations/Implications
- References

Report on outcome of a workshop:
- Abstract
- Rationale for workshop; reasons to learn more about topic
- Main points made at workshop
- Insights gained from talks and discussions
- Conclusions and final recommendations

Description of the development of educational tool or product:
- Abstract
- Rationale for project
- Brief description of final product (e.g. curriculum, model policy)
- Lessons learned from development process
- Recommendations to others attempting similar work
- Recommendations on use of product

Submission procedures

Authors can submit either an article or a query to Lucy Hutcherson at luhutche@chicagowilderness.org. Queries should include a thorough abstract of the intended topic. Articles and all accompanying graphic files should be submitted electronically to Lucy. Be sure to include the author's contact information. Submissions can also be saved on a disc and mailed to Lucy at the Chicago Zoological Society/Brookfield Zoo, 3300 Golf Road, Brookfield, IL 60513.

Although articles will be accepted on an ongoing basis for consideration in all upcoming issues, a rough schedule of deadlines follows:
- For March issues: first drafts will be due the second Friday of the preceding November,
- For July issues: first drafts will be due the second Friday of the preceding April,
- For November issues: first drafts will be due the second Friday of the preceding July.

Authors are welcome to submit articles that have already been published, as long as the article contains specific implications for Chicago Wilderness, and the author observes copyright law and has obtained the appropriate permissions for reprinting. If your submission has been published elsewhere, please indicate where and when it was published so we can note this in the journal.

The journal's editorial board recommends that if possible, authors should work with their internal PR departments for assistance in translating specialized information into material that is accessible to a more general audience. In addition, members of the journal's editorial board will partner with authors to adapt the style and format of articles to be most useful to the broad Chicago Wilderness audience.

For more information, contact Lucy Hutcherson at (708) 485-0263, ext. 253.

About the *Chicago Wilderness Journal*

The *CW Journal* is published by the Chicago Region Biodiversity Council (Chicago Wilderness) on its web site (www.chicagowilderness.org) three times per year: in March, July, and November.

An editorial board composed of scientists, sustainability professionals, education, and communication specialists from Chicago Wilderness member organizations guide the production of each issue in accordance with the mission of the journal and the goals of Chicago Wilderness. The opinions expressed in this journal, however, are solely those of the authors.

Mission of the Chicago Wilderness Journal:

1. Facilitate the sharing of results and lessons learned from member-initiated projects and activities, including coalition-funded projects, team activities or the work of individual member organizations that would be useful to the wider membership;
2. Through easily consumable articles discuss practical implications, interpret data, and/or make recommendations about issues within the areas of science, land management, sustainability, education, and communication in the Chicago region;
3. Foster a sense of community among Chicago Wilderness members and improve members' ability to communicate with diverse audiences.

For information about how to submit articles please refer to the Guidelines to Authors posted on the *Journal's* home page. For other inquiries about this publication, please contact Lucy Hutcherson at luhutche@chicagowilderness.org.

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