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THE HUDSON RIVER ENVIRONMENTAL SOCIETY

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In This Issue

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The Hudson River is Warming

By Michael L. Pace and David A. Seekell

While there are many long-term air temperature data from numerous weather stations in the United States, similar records for water temperature are rare. Such a record, however, exists for the Hudson River based on direct measurements of river temperature made daily at the Poughkeepsie Water Treatment Facility (PWTF). This record goes back to 1908 and provides an opportunity to analyze temperature change and to benchmark river temperatures relative to future climate that will likely be much warmer.

The Hudson water temperature data were initially assembled in 1990 by Donna Ashizawa, a summer research student, at the Cary Institute of Ecosystem Studies. Working with Dr. Jonathan Cole and with help from PWTF personnel, Ashizawa computerized daily temperatures values from written and printed records, many of which were stored in dusty old boxes. In 2006 we updated the temperature data of Ashizawa and Cole with the help of Mathew Geho of PWTF. We also reviewed other temperature data from the Hudson including continuous temperature measurements made by the United States Geological Survey (USGS) at a number of sites on the river over shorter time periods. We found that the annual mean temperature of the Hudson River has increased and that the rate of temperature increase is accelerating.

Poughkeepsie is an ideal site for measuring river temperature. The location is roughly in the middle of the estuarine section of the river that extends from Troy to Battery Park. Poughkeepsie usually is above the reach of salt water, except in the driest summers when low salinity water can travel farther upriver. The river is also large and very well mixed at Poughkeepsie, and therefore, local conditions are less variable relative to upriver stations where temperature might be more influenced by local tributaries and uneven flow rates. Poughkeepsie is also less influenced by the seasonal gradients that develop in the Hudson such that upstream areas are colder than downstream areas during winter and spring and the reverse is true in the summer and fall. The Poughkeepsie site thus provides a good index of overall temperature conditions in the system.

The Hudson is warming, but the magnitude of any trend depends on your starting point. We considered two time periods to evaluate the record – the full period 1908-2006 (Figure 1 - Page 2) and a shorter period from 1946-2006. Some data are missing for the years prior to 1946, and in some cases the data are so limited that an annual average was not calculated. After 1946, the temperature records are more consistent and an annual average could be calculated for all years, providing a more reliable basis for evaluating a trend. The long-term annual mean temperature of the Hudson River for these two time frames is about the same: 12.4° C for 1908-2006 and 12.5° C for 1946-2006. The coolest year of the record was 1922 when the mean temperature was 10.6° C. The warmest year was 1998 with a mean temperature of 13.8° C. Statistical analysis of the data confirms that there has been a significant long-term warming trend for the entire record (1908-2006) and for the period of continuous measurement (1946-2006).

But let's go back to the beginning. In 1908 the Hudson was warm (Figure 1). Indeed, river temperatures were above normal (the long term average) for the first 10 years of the record, and this warm period influences the trend. The trend from 1908 to 2006 is a warming of 0.009° C per year. The trend for 1946-2006 is 0.017° C per year. In either case there has been a warming, but the magnitude of the trend for the entire record is strongly influenced by the relatively warm water temperatures of the first 10-15 years of the record.

Figure 1: Hudson River annual mean temperature calculated from daily measurements at Poughkeepsie

In the 1920s and 1930s, the river was colder. The next few decades brought variable conditions – both relatively warm and cold years. More recently (1980 onward), the river has been warm with temperatures above the long-term average in almost every year. This pattern is best depicted in a temperatures anomaly graph (Figure 2). The "anomalies" are simply the difference between the long-term average temperature of the river from 1908-2006 (12.4° C) or 1946-2006 (12.5° C) and the measured average of a specific year. For example, in 1984 the mean annual temperature of the Hudson was 13.0° C and so the river had

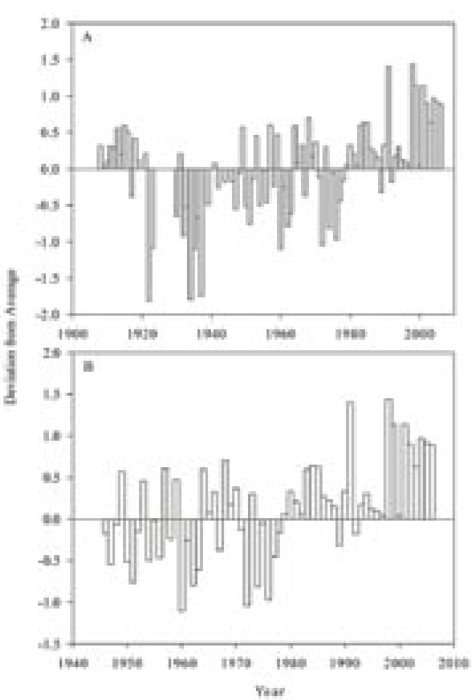

Figure 2: Annual deviation of temperature from the long term average for the time periods 1908-2006 (upper) and 1946-2006 (lower).

a positive temperature anomaly of 0.6 degrees relative to the 1908-2006 period. From the anomaly graph, the shift from negative (colder than average years) to positive (warmer than average years) is apparent for both the longer and shorter time periods.

There are many possible causes for changes in water temperature, including changes in land use, changes in run-off, and urbanization. Of these factors, the input of freshwater related to run-off is particularly important. Inputs of freshwater to the Hudson River estuary are measured at the Green Island Dam located in Troy, New York. This input is referred to as discharge and reported as cubic feet per second (or cubic meters per second). The Green Island Dam record covers the period of the temperature record and so we analyzed the relationship between river discharge and water temperature. The Hudson tends to be warmer in years of low discharge (i.e. dry years) and cooler in hears of high discharge. If change in discharge was causing increases in water temperature, we would expect a decrease in discharge over time. However, over the period of the record, there was no trend in the annual average discharge. Hence, while variation in discharge explains some of the year-to-year differences in temperature, changes in discharge do not explain the long-term warming trend.

Climate warming is another possible factor that could drive increases in river temperatures. Regionally, air temperatures have been increasing (Trombulak and Wilson 2004; Burns et al. 2007) and historical air temperature data for Poughkeepsie, New York demonstrate that trend (Figure 3). These data, available from the United States Historical Climatology Network and covering the past 130 years, are best suited for long-term analysis because they are evaluated and adjusted for any changes in measurement techniques, time of observation bias, variation due to station relocation, and urban warming. We found a positive correlation between annual mean air temperature and annual mean river temperature for both the 1908-2006 and 1946-2006 time periods. We conclude that the increase in air temperature related to regional climate change is the main feature driving increases in Hudson River temperatures.

We evaluated average monthly water temperatures to assess if there were seasonal trends in the warming of the Hudson. These temperatures were calculated from means of the daily values for each month over each year. There were no trends in winter water temperatures (December-March). The months of April through August, however, all had significant positive temperature trends. The months of October and November were slightly cooler over the record although these trends were not statistically significant. Overall, the warming of the river is occurring in the spring through late summer period but not in the autumn or winter.

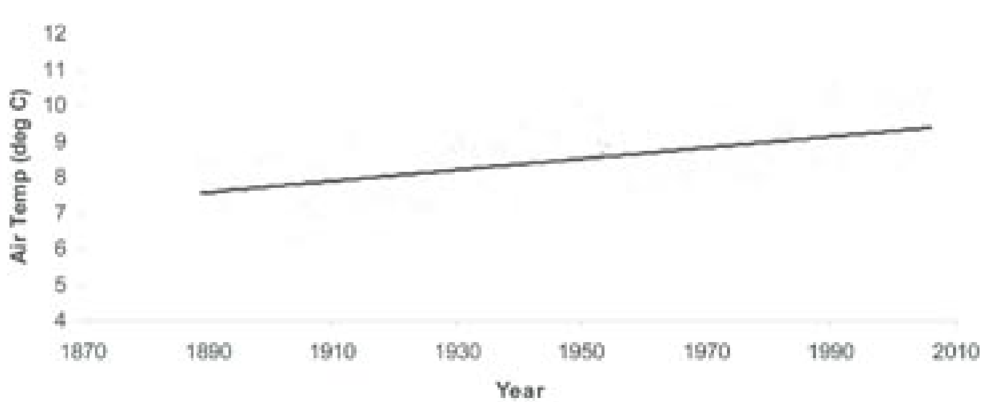

Figure 3: Annual average air temperature at Poughkeepsie.

How much hotter is the Hudson and what will occur in the future? The Hudson has warmed by one degree Celsius since 1946, and the rate of temperature increase appears to be accelerating in recent years. We analyzed the rate of change in temperature by breaking the data into shorter time periods. For example, over the time period 1946-2006 as noted above the temperature increased 0.017° C per year. Over the last twenty years (1986-2006) the rate of temperature increase has been 0.029° C per year. Looking at the data another way, prior to 1998 the annual average temperature of the Hudson exceeded 13° C in only two years (1968 and 1988). Since 1998, river temperature exceeded 13° C in all years except 2000.

The warming of the Hudson is consistent with other studies of water and air temperature change in the northeastern United States. Changing temperature can alter the abundance of aquatic populations and the composition of estuarine communities. Many ecosystem properties — including the cycling and fates of nitrogen, phosphorus, and organic carbon, as well as important physical variables such as salinity and water residence time — are also likely to change with warming. Long-term temperature increase looms as an important force for environmental change in aquatic systems, the impacts of which will become ever more evident due to anthropogenic greenhouse gas emissions.

We want to highlight the importance of continuing temperature measurement programs such as the one maintained for the Hudson by the PWTF, which has provided crucial evidence that the Hudson River is warming. In concert with monitoring efforts such as those recently established under the rubric Hudson River Environmental Continuous Observing System (see www.caryinstitute.org/HRECOS), these long-term data will be invaluable for evaluating the environmental and societal consequences of climate change.

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The State of the Hudson River and its Watershed

A Conference examining the health of the Hudson ecosystem

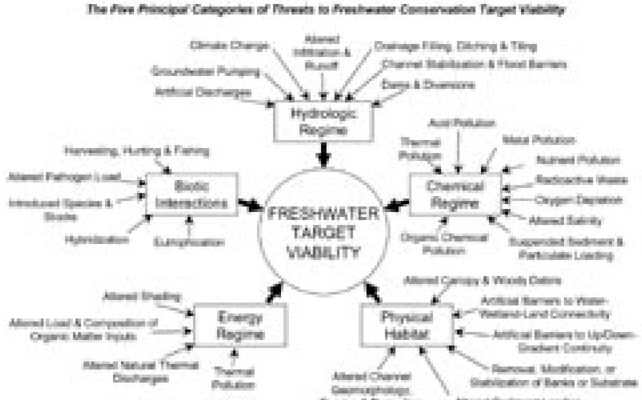
Tuesday, September 29th and Wednesday, September 30th, 2009

What can we say about the state of the Hudson River and its watershed 400 years after Henry Hudson? This is the subject of a two-day conference planned for this quadricentennial year and is being organized by HRES jointly with numerous other Hudson Valley organizations, including The Nature Conservancy, the Hudson River Estuary Program, the Hudson River National Estuarine Research Reserve, the U.S. Geological Survey, the Hudson River Watershed Alliance, and Scenic Hudson. The conference is being hosted by the Henry A. Wallace Visitor and Education Center at the Franklin D. Roosevelt Presidential Library and Museum in Hyde Park, New York and is scheduled for September 29-30, 2009.

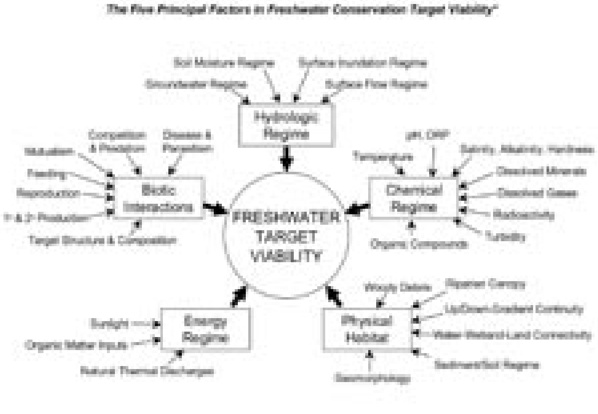
The conference will be organized around the elements that comprise freshwater ecosystems (Figure 1). Presentations on current conditions, on trends in estuarine and freshwater hydrology, physical habitat, water quality, ecosystem energetics, and biotic community dynamics will focus on the ecological integrity of the Hudson River and its tributaries. Human impacts on any of these elements may affect the health of our rivers and streams (Figure 2). The conference will also address the current status and new trends in environmental policy and management as they relate to each of these elements, and the Wallace Center will be providing presentations on the cultural aspects of the Hudson River environs.

For more information on the series, contact Mark Vian at vian.mark@gmail.com.

The Five Principal Categories of Threats to Freshwater Conservation Target Viability



*The Five Principal Factors in Freshwater Conservation Target Viability**



Rising Waters:
A Planning Effort to Help Hudson Valley Communities Adapt to Climate Change

By David VanLuven

Over the last 20 years, we environmentalists have had a lot of trouble advancing many important conservation strategies. One key reason is that actions that are viewed as being "environmental" are politically weak and only have access to a subset of the private, state, and federal dollars that might be leveraged to move them forward. The prospect of climate change presents a huge opportunity to transform this state of affairs.

Climate change is underway and it will continue to affect the Hudson Valley for decades even if all greenhouse gas emissions are stopped immediately. We will have more intense storms, greater flooding, more frequent heat waves, warmer winters, and higher sea levels. While these effects of climate change have serious implications, how we prepare for and respond to these effects is equally crucial. Who wants to see the Hudson River Estuary converted to a 153-mile culvert lined with 20-ft high sea walls to contain the rising waters?

Climate change will have consequences for natural systems throughout the region, and for all sectors of society. Because of the broad scope of these impacts, The Nature Conservancy's Eastern NY Chapter launched the *Rising Waters* planning process to help Hudson Valley communities adapt to climate change in ways that will protect both people and nature.

The *Rising Waters* Steering Committee is a partnership composed of The Nature Conservancy, the Cary Institute for Ecosystem Studies, DEC's Hudson River Estuary Program, DEC/NOAA's Hudson River National Estuarine Research Reserve, NYS Water Resources Institute at Cornell University, and Sustainable Hudson Valley. The project has three objectives:

- Highlight all of the Hudson Valley stakeholders that will be affected by climate change;
- Find solutions that will protect both people and the environment;
- Build the necessary political clout and access to resources to make these solutions happen.

Bio-Economic Research Associates (bio-era), an internationally acclaimed consulting firm, is facilitating the planning process.

We are using multistakeholder scenario planning to accomplish these objectives, an approach first developed by Pierre Wacke and Ted Newland at Royal Dutch Shell in the 1970s. While corporations have used multistakeholder scenario planning extensively over the last three decades, it is a relatively new approach for planning efforts initiated by conservation organizations.

Scenario planning basically involves building potential futures that convert complex situations filled with uncertainty into stories that different stakeholders can understand and think about productively. These scenarios are not predictions! Instead, they are the starting points for conversations and innovative thinking.

Throughout 2008, more than 150 people representing 30 different stakeholder categories – railroads, agriculture, road infrastructure, environmental conservation, county planning, insurance, and more – participated in a series of large and small *Rising Waters* meetings.

Through these meetings, we built four scenarios describing four potential futures for the Hudson Valley. We set a 20-year window for these scenarios because that is

General climate change projections used in the Rising Waters planning process

	By 2030	By 2080-2100
Average Annual Temperature	2.2° F warmer	6.2° F warmer
Average Winter Temperature	3.3° F warmer	7.8° F warmer
Sea Level	6 inches	24-36 inches
Precipitation	0.6% increase	8% increase
Snow	Area of snow cover will contract; more precipitation will fall as rain instead of snow; snow will be denser and more slushy; snow covered days will decrease by 14-16 days since 2001	Area of snow cover will contract; more precipitation will fall as rain instead of snow; snow will be denser and more slushy; snow covered days will decrease by 9 days per month; 38% shorter snow season in spring
Major Storms	Increase in intensity of strong storms; no definitive link between warming and hurricane frequency	Increase in intensity of strong storms; no definitive link between warming and hurricane frequency
Extreme Rainfall	Increase in winter precipitation; maximum precipitation in 5 days increases approximately 10%; one more day of rain >2"/year; precipitation intensity (average amount of rain that falls on any given rainy day) increases 7-8%	20-30% increase in winter precipitation; maximum precipitation in 5 days increases approximately 20%; approximately 1.5 more days of rain >2"/year; precipitation intensity increases 13-14%
Heat Waves	Average of 22 day each year over 90° F and 3 days over 100° F annually	Average of 54 days over 90° F and 16 days over 100° F annually
Drought	Little change; currently, a short term (1-3 months) drought occurs every 2-3 years	Slight increase in frequency of short and medium term (3-6 months) drought
Timing of Seasons	On average, spring (first leaf, first bloom) earlier by 3 days, first frost 3 days later, last frost 2 days earlier, growing season 5 days longer; ice in later, ice-out 1 week earlier; peak stream flow 4 days earlier	On average, spring earlier by 10 days, last frost 19 days earlier, first frost 13 days later, growing season 5 weeks longer; ice in later, many southern Hudson Valley lakes often stay ice free; peak stream flow 12 days earlier
Regional Sea Surface Temperature	2° F warmer	6.5° F warmer

the far end of effective planning coupled with implementation, at least in the experience of the many participants. We also set the study area as the lower half of the Hudson River watershed, covering the 10 counties between Troy and Manhattan whose lands feed the Hudson River. At 5,300 square miles, the project area is large for multi-stakeholder scenario planning, but the participants felt that the broad extent was necessary to capture the many different climate-related factors that would be affecting each of their interests.

Climate Change Projections

Scientific projections of climate change on the Hudson Valley vary widely, depending on the subtle parameters and assumptions of the models being run. For the purposes of *Rising Waters*, the participants decided to follow the mid-case projections of the Intergovernmental Panel on Climate Change (IPCC, 2007), augmented with modeling by the New York City Department of Environmental Conservation Climate Change Program (NYC DEP, 2008) and the Northeast Climate Impacts Assessment (NECIA) (Frumhoff, *et al*, 2007). The sources are a solid foundation for our planning purposes because they each have sound, peer-reviewed methodologies and cite specific figures or ranges for the Hudson Valley and Northeastern U.S.

The mid-case projections are useful because they are set on assumptions born directly from trends we see in today's world, including increasing global population until the mid 21st century, new and more efficient technologies, and globalization, and (some) income convergence globally. Even the worst-case and best-case IPCC projections produce very similar outcomes when projected over the next 10-20 years – the general window of *Rising Waters*. Only in longer-term projections spanning 40 to 100 years do the projections begin to express highly different outcomes.

The New York City Department of Environmental Protection report was the best resource for projected sea level rise, temperature change, and precipitation change because it was more specific to southeastern New York. For the same reasons, the NECIA report had the best projections for changes in winter temperature, snow cover, heat waves, extreme rainfall, drought, and seasonal changes.

We anticipate that climate change impacts in the Hudson Valley will include more extreme precipitation, essentially in the form of more intense storms that will carry a greater likelihood of flooding. We will also see more frequent strings of consecutive days over 90° F in the summer, while winter days below zero will only occur a few times each year.

Modeled projections for the amount of sea level rise vary quite widely, but the general expectation now is that sea level in the Northeastern U.S. will increase by approximately 6 feet over the next 100 years. This increase will be slow in the next 20 years, but is expected to accelerate in each ensuing decade.

Scenarios

The four scenarios we collectively developed were built around two key uncertainties:

1. Will we prepare for climate change early, or will we wait?
2. Will our responses focus on engineering, or will they emphasize natural systems?

Each scenario used a different combination of these factors to present different potential futures for the Hudson Valley.

In one scenario, for example, a rebounding economy fuels extensive sprawl-style development. Federal funds become available for state and local adaptation efforts, and environmental advocates are joined by religious groups in promoting conservation of natural systems over capital-intensive infrastructure projects. Then, the Valley experiences a period of extensive, very damaging floods. These floods trigger a public backlash against "nature-loving" activities and spur a demand for engineered solutions that are possible within the strong economy.

In another scenario, a plodding economy slows development. Nonetheless, there is a strong state and federal push for adaptation efforts. Then, the Valley experiences extensive and very damaging floods. In response, state and federal agencies invest in a few big infrastructure projects, but costs quickly outstrip public funding. Then, more damaging floods occur, and below one of the big projects flooding severely damages a town and corporate facility. Lawsuits ensue. Amid the damage and soaring costs, a public and political backlash questioning the cost effectiveness of engineered solutions drives strong land use and water management regulations.

It is important to remember that these scenarios, which are spelled out in much more detail, are not predictions of the future. Instead, they are carefully crafted stories that translate the complexity of climate change into concrete terms that different stakeholders can consider in the context of their individual interests. As a result, they are a powerful tool for identifying and testing response strategies.

In the 2008 meetings, *Rising Waters* participants generated a sprawling list of more than 200 different response strategies. These strategies consider stormwater management and flood insurance, emergency responses, education, wetlands restoration, transportation, research, and more. Now, we are now culling through the list to identify the subset of strategies that will have the greatest likelihood of success in all four scenarios, that have champions who can find resources and move them forward, that are cost effective, that are durable, and that will yield benefits to both people and nature.

The *Rising Waters* planning process will be winding down in the spring of 2009, but the effort will by no means be completed. In fact, the planning process will only be successful if it launches diverse coalitions to move climate change adaptation strategies from talk to implementation. Our vision is that different groups of stakeholders will take different strategies and advance them to the extent that it is in their best interests. Strategies with broad benefits would ideally have coalitions representing a broad set of interests. Strategies with more focused benefits are expected to spark more focused coalitions.

Yet the strategies generated by *Rising Waters* will likely not be the most transformative aspect of the effort. The strategies we have generated so far are in many ways the same things that people have been talking about for decades. Through the multi-stakeholder scenario planning process, we have put as much effort into laying the broad foundations for implementation as we have into generating the strategies. If our efforts in 2008 and 2009 and beyond are successful, the strategies we generate will be refined and put forward by diverse coalitions that have more political clout than groups of environmental advocates have had in the past. The hope is that coalitions will be able to tap a broader set of resources for action because the strategies will more clearly yield social and economic benefits, not just environmental benefits. And we all know that more political clout plus more dollars dramatically increase the likelihood of implementation.

Rising Waters is a collective effort to use climate change as a catalyst for action. The participation we have seen from many different stakeholders over the last year gives me great hope for the future, despite the magnitude of the changes and challenges we face.

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David VanLuven is the Hudson River Estuary Director at the Eastern NY Chapter of the Nature Conservancy.

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hres@nycap.rr.com

One of the key planning groups in the *Rising Waters* effort was the Scenarios Team which included: (back row) Fred Schuepfer (HDR/LMS), Stuart Findlay (Cary Institute of Ecosystem Studies), Gary Kleppel (SUNY Albany), Victor Melendez (private consultant), Steve Aldrich (bio-era), Michael O'Hara (private consultant), Fred Koontz (Teatown Lake Reservation), Susan Riha (Cornell University), Melanie Modjeska (Septon Development Group), Robert Weireter (SwissRe), Ellen Weiss (The Nature Conservancy), David VanLuven (The Nature Conservancy), Katy Dunlap (Hudson River Watershed Alliance), Fran Dunwell (NYS DEC Hudson River Estuary Prog.), Ann Davis (Marist College); (front row) Betsy Blair (Hudson River Nat. Estuarine Research Reserve), Katie Dolan (The Nature Conservancy), Kristin Marcell (NYS DEC Hudson River Estuary Prog.), Rosemarie Baglia (Cornell Coop. Ext-Orange County), Joseph Heller (Natural Resources Conservation Service), Melissa Everett (Sustainable Hudson Valley), Scott Chase (Dutchess County Planning), Brian Thomas (bio-era)

Welcome New HRES Members!

The Hudson River Environmental Society welcomes the following new members.

John McKeeby
Gerard Chartier
John E. Thompson
Karen Helgers
Larry Barnthouse
Louise I. King
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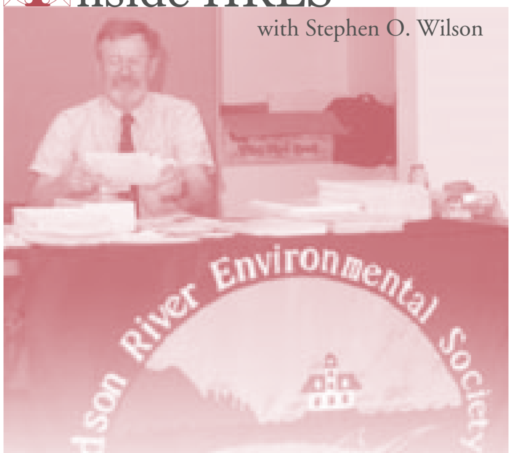
William Schuster
Joseph T. Bridges
Kathryn K. Macri
Ralph M. Brown
Liesl Hotaling
Philip Ehrensaft
Richard H Stearns
David Clouser
Rebecca Platel

In a reflection of the far-reaching impact of the Hudson River on its surrounding valleys and hills, our new members bring a wide range of expertise and interests to the Society. They represent local government planning agencies, not–for-profit conservation organizations, consulting firms, academic institutions and businesses. HRES appeals to this diverse audience because it encourages research on the river, provides a forum for communication, and makes the results of environmental research available and accessible to everyone with an interest in the Hudson River.

With the Hudson's Quadricentennial celebration, 2009 promises to be an exciting year for us. Now is the time to join and be sure you are "in the loop."

HRES is proud to be a partner in the Hudson-Fulton-Champlain Quadricentennial Celebrations

Inside HRES



with Stephen O. Wilson

HRES produced three events in 2008, all of which were successful. We were stimulated by the excellent presentations, grateful for the generous support of our sponsors and thrilled with how many members participated. Special thanks go out to Mark Vian, Program Chair, for his hard work putting together these terrific programs.

Ecosystem-based Management
13 June 2008 at Marist College

85 participants, 8 speakers, 4 cosponsors

Annual Meeting
11 September 2008 at the Newburgh Yacht Club

We honored Fran Dunwell, Coordinator of the Hudson River Estuary Program with our Distinguished Career Award and Michael Landin with our Outstanding Communicator Award. In addition, Dutchess County Legislator Joel Tyner addressed those in attendance.

45 participants, 2 cosponsors

Small Unregulated Wetlands
28 October 2008 at Norrie Point Environmental Center in Staatsburg

125 participants, 13 speakers, 10 cosponsors

We have high hopes for our 2009 events. Commencing this spring and continuing in the fall, we will produce a series of programs on The State of the Hudson River and its Watershed. In November, we will hold an event to coincide with the Hudson-Fulton-Champlain Quadricentennial, entitled Historical Ecology of the Hudson Valley.

All HRES activities are organized by our committees, including planning our future programs, increasing our membership, identifying potential Board members and recognizing individuals who merit HRES awards. We are actively seeking new committee members to serve on each of our five committees:

<u>Program Committee</u> identifies topics for at least three public conferences per year, designates a conference manager for each, presents the concept for each conference program to the Board for approval, oversees the design and conduct of these programs;

<u>Awards Committee</u> identifies candidates who have distinguished themselves as resource managers, researchers, significant communicators, and educators in the Hudson River Valley, and arranges the presentation of awards and their publicity;

<u>Membership & Marketing Committee</u> encourages the sustenance of our individual, corporate and institutional memberships, recruits new members and publicizes the work of the Society;

<u>Publications Committee</u> is responsible for the planning, editing and publishing of all of the Society's publications, including our newsletter, *Currents*. A subcommittee oversees the design and operation of our web site;

<u>Nominations Committee</u> identifies members as potential candidates for election to the Board, invites members to suggest candidates and ensures that elections are fair and conducted properly. The committee also recommends a slate of Society Officers.

Our by-laws require that committees have at least one non-board member. If you have an interest in participating in any of these aspects of the operations of your Society, please contact me, or Bill Shaw (HRES President), so that we may put you in touch with the committee chairperson. We encourage you to become involved!

HRES was founded in 1970 to help science enlighten decision-making by bringing together scientists, educators and decision makers.

Currents
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Hudson River Environmental Society

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