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CHAPTER THIRTEEN

The Hudson's Future

When an author submits the final copy of their book to a publisher, they are instantly afflicted with what my friend Rick Ostfeld calls "writer's remorse". Should I have dropped all that stuff about A, B, and C? No one will want to read that. Why didn't I write anything about subjects X, Y, and Z? Oh no, here's a mistake, .., and another! Whatever possessed me to think I was qualified to write a book about the Hudson at all?

I'm certainly not going to tell you all of the problems that popped into my mind after I submitted the manuscript of this book to the publisher. One omission, though, seems so obvious and so important that it is worth correcting. The primer is all about how the Hudson's ecosystem works today, and the changes that occurred in the past. But what about the Hudson's future? Of course, it's hard to write about the future with the same sense of certainty that one can have about the present or the past, but in some ways the future of the Hudson is more interesting than its past or present, because we have some control over the Hudson's future. So with the clear understanding that it is impossible to write with both precision and certainty about the future, here are a few thoughts about the future of the Hudson River ecosystem.

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The river is going to change

Perhaps the most obvious characteristic of the Hudson over the past century is how dynamic the ecosystem has been, largely in response to human actions. The channel was reshaped, nutrient loading increased 10- to 100-fold, huge volumes of sewage and toxins were dumped into the river for decades before being controlled, abundant stocks of fish and shellfish were overfished to the point of ecological and commercial irrelevance, and dozens of non-native species were added willy-nilly to the river (see Chapters 9-12 for details) Some of these changes were more or less anticipated (sewage pollution, loss of commercial fishes), and others were complete surprises (PCB contamination, the arrival of specific invaders such as zebra mussels).

There is no reason to think that the Hudson will be any less dynamic in the near future. Human use of the river will continue to be varied and intensive, and these uses, along with natural forces, will cause large changes to the Hudson's ecosystem. The changing forces affecting the river, and the river's response, will be complex and highly varied, and it is impossible to offer a thorough account of the Hudson's future without having a very good crystal ball. Even without a crystal ball, I can suggest three classes of change that are likely to affect the Hudson.

The first and happiest class includes the long-term improvements that are likely to result from management actions that have recently been put onto place. For example, we can reasonably expect to see long-term improvement in fish stocks as better fisheries management (e.g., better interstate cooperation, stricter harvest regulation, including the moratorium on Atlantic sturgeon catches) reduces unsustainable harvests and allows depleted stocks to recover, as happened with striped bass in the late 20th century (see pp. 166-167). If these protective regulations are allowed to remain in place, and barring any other harmful changes to the ecosystem (see below), the Hudson may again teem with shad, river herring, and sturgeons.

Likewise, elimination or control of point-source pollution in the late 20th century has already greatly improved water quality in the Hudson (pp. 104-105, 137, 143). Problems from persistent pollutants such as metals and PCBs are likely to continue to lessen as the worst sites are cleaned up and restored (e.g., the massive project to remove PCBs from the upper Hudson), and as the river buries or washes out residual pollution from the 19th and 20th centuries. It will be some time before most of this legacy of uncontrolled pollution disappears and all of the Hudson's fish and shellfish are wholesome to eat, but at least we can reasonably look forward to continued progress.

A second class of changes that certainly will be important in the Hudson's future includes large changes that we can anticipate but have not yet dealt with effectively. I offer just two examples.

Climate change is the elephant in the room for the Hudson's future. At this writing (2012), scientists around the world have agreed that human-caused changes to the climate are already occurring and will become large and widespread by the end of the 21st century (see www.ipcc.ch for the details). However, the world's governments have not yet come up with an effective policy response to (or sometimes even acknowledged) this problem, meaning that the Hudson will almost certainly be subject to large climate-induced changes in the coming decades. A changing climate will mean many

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things for the Hudson and its inhabitants. I will mention just three aspects of this problem – temperature, extreme events, and rising sea level.

Projections for eastern New York suggest that temperatures will rise 3-5 °F by the 2050s and 4-7.5 °F by the 2080s (e.g., http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf). These rising temperatures will have many direct and indirect effects on the river and its watershed. Here are a few examples. Animals like the tomcod that require cool waters (Chapter 6) may disappear from the Hudson, to be supplanted by heat-loving species from the south. Except for warm-blooded animals, warmer temperatures mean faster rates of processes like production, respiration, and decomposition. This faster pace of life will lead to very pervasive and hard-to-predict changes in the ecosystem. Ice will cover less of the river for less time, and have smaller effects on the ecosystem. The timing of seasonal events (what scientists call "phenology") will change. The changes that we are already seeing in the Hudson Valley in earlier leaf-out of plants and spring migration of birds and fishes will accelerate. One interesting possibility is that seasonal events that used to be matched will become mismatched as temperatures change, with important ecological consequences. For example, it looks likes like the degree of overlap between the timing of appearance of baby fishes and the spring zooplankton bloom determines how well the fish do that year (p. 85). If the baby fish and the zooplankton respond differently to warming, then a gap may appear and widen between the timing of the zooplankton bloom and the needs of the fish, and fish populations may suffer. Scientists do not yet know how common or serious such mismatches will be as the

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climate changes. Finally, as the changing climate changes the local economic viability of activities such as agriculture and tourism, land use patterns in the Hudson's watershed will change, with subtle but pervasive effects that are difficult to predict.

In addition to warmer temperatures, eastern New York probably will be wetter and be subject to more intense storms in the future. For instance, a recent study (http://www.eenews.net/assets/2012/02/15/document_cw_01.pdf) projected that hurricane storm surges of a size that used to occur in New York City every 100 years on average will occur every 3-20 years by the year 2100. These intensified storms will affect the ecosystem. Probably more important to the ecosystem, though, will be any human engineering responses (e.g., storm surge barriers at New York City) to protect life and property from storms.

As important as these changes will be, perhaps the most important effect of global climate change on the Hudson will be the rise in sea level. Scientists are not yet able to project rises in sea level very precisely, but current best estimates are for sea level at New York City to rise 0.3-0.6 m (12-23 inches) by the 2080s, but rises of 1.0-1.4 m (41-55 inches) are possible (http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf). (If the 2080s seem remote to you, remember that most of the babies born this year will be alive in the 2080s, and so will have to deal with these higher sea levels). Because the Hudson is essentially at sea level all the way to Troy (Chapter 1), rises in sea level will affect the entire estuary, from New York City to Troy.

The effects of rising sea level are going to be so pervasive that it is difficult to provide a brief summary, but here are some examples.

Unless sedimentation can keep up with rising sea level (which seems unlikely), some of the Hudson's wetlands will be drowned out (Chapter 8), and many of the beds of submerged plants (whose growth is controlled by light levels, and therefore water depth – Chapters 2, 7) will disappear. One way to prevent or lessen the loss of these shallow-water habitats would be to let the rising Hudson flood areas that are now land, converting them into vegetated aquatic habitats, but it seems very unlikely that people will abandon valuable riverside real estate to the river. Because these vegetated shallow-water ecosystems are so valuable ecologically (Chapters 7, 8), their loss will harm populations of fish and wildlife in the Hudson.

Rising sea level should also affect the salinity zones of the Hudson. Salinity has large effects on ecological processes and populations of plants and animals (Chapters 3, 6-8), so as rising sea level shifts salinity zones, populations of plants and animals will shift as well. Changed salinity will also affect the suitability of the Hudson as a drinking water source for riverside communities.

Of course, rising sea level will endanger human infrastructure near the Hudson, including rail lines, houses, businesses, roads, parklands, and so on. Our responses to these dangers – whether thoughtful and forward-thinking, or reactive and panicked – will to a considerable degree determine whether the Hudson's habitats, especially the shallows, are further damaged by careless human actions, or protected (or even restored) for future generations. For more information on the implications of rising sea level for New York, see http://www.dec.ny.gov/energy/45202.html and http://www.nature.org/media/newyork/rw_070509_exec.pdf.

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Poorly controlled species invasions are a second area where we can anticipate large changes that we are not yet doing a good job controlling. Current invasion rates in and around the Hudson are high and steady (Chapter 12), because we have not yet done a very good job controlling the pathways that are bringing non-native species into the country (e.g., ballast water, the pet and horticulture trades, etc.). As a result, we can expect continued high rates of invasion into the Hudson, its tributaries, and its watershed. Because many of these invaders have large ecological and economic impacts, we can also anticipate high rates of change from invaders. Although we can name some likely invaders (e.g., silver and bighead carp, round goby, New Zealand mudsnail, "killer shrimp" = *Dikerogammarus villosus*, viral hemorrhagic septicemia virus), we can't be specific about which invaders will arise and establish, when they will appear, or precisely what impacts they will have. We can be confident, however, that troublesome new invaders will appear and present management challenges.

Finally, a third important class of changes will be surprises: changes that we neither anticipate nor understand at first. I can't say anything more about the nature, timing, or importance of these surprises (if I knew what they were going to be, they wouldn't be surprises!). Lest you think that surprises are unlikely, I point out that such surprises have occurred regularly both in the environmental history of the Hudson and our region (the discovery of PCB pollution in 1970, the emergence of Lyme disease in the watershed, the arrival of zebra mussels in North America in the 1980s, changing patterns of land use in the watershed after the World Trade Center

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attack in 2001). It seems foolish to assume that we have suddenly become so wise that we won't be surprised again in the future.

The likely occurrence of surprises in the future suggests that we should have in place good programs to monitor the river, and policy frameworks that let us react quickly and intelligently to surprises when they occur. Good monitoring lets us detect surprises as early as possible; in many cases, early responses are more effective and cost less than responses that are delayed. The current monitoring of the Hudson is a mixed bag. Programs to monitor physical and chemical conditions in the river are progressing rapidly. The Hudson River Environmental Conditions Observing System (www.hrecos.org) is an example of an excellent cooperative program that uses modern technology to measure physical and chemical conditions in the river and make the data publically available. Biological monitoring is advancing less rapidly, and is being conducted by several organizations, including the electric generating utilities, the New York State Department of Environmental Conservation, and research organizations like the Cary Institute of Ecosystem Studies. Every monitoring program on the Hudson leads a more or less perilous existence, and is regularly threatened with shutdown when budgets tighten or political winds shift. If we are serious about protecting and managing the Hudson wisely, we really must commit to good, long-term monitoring of the river, including biological monitoring. If we are not aware of the condition of the river, including any surprising changes, we can hardly be in a position to manage it well.

Hindsight provides a poignant local example. If we had had better systems in place to monitor the Hudson or to react to the late-breaking information that appeared in 1970 about PCB contamination of the Hudson, we might not have allowed the Fort Edward dam to be removed in 1973 (Chapter 9). This would have kept much of the PCB contamination bottled up in the Fort Edward pool, and probably very greatly reduced the monetary, social, and environmental costs of PCB removal.

Ideally, our environmental policies and management should be flexible enough to accommodate surprises. Rigid management approaches based on how the Hudson works in 2012, however excellent for 2012, will fail us as the river changes in the future. It is my impression that neither governmental agencies nor NGOs (non-governmental organizations) are yet fully comfortable with the adaptive management approaches that might provide the flexibility needed to deal with future surprises.

Scientific understanding of the river will have to evolve along with the river

It is natural to think that some day scientists will understand the Hudson well enough that we can stop studying it. However, I have just argued that the Hudson is going to keep changing over the coming decades for a variety of reasons. Because the Hudson will continue to change rapidly, our understanding of the river will keep going out of date. Likewise, scientifically based management approaches that were sound in yesterday's river will have to be applied cautiously, modified, or even discarded in tomorrow's river.

For example, we knew quite a lot about how the Hudson's ecosystem worked and how to manage the river by 1991, the year that zebra mussels first appeared in the river. This invader so

profoundly changed the ecosystem (Chapter 12) that much of our understanding of the river no longer applied or, at best, needed to be retested to make sure that it was still valid. To cite just one example, before zebra mussels invaded, the number of young fishes in the river did not depend very strongly on how wet the weather was. However, after zebra mussels came in, fish populations became quite sensitive to river flow. A good manager's response to changes in river flow might be very different in the pre-zebra mussel river than in the post-zebra mussel river. So if we wish to understand and wisely manage the new manifestations of the Hudson ecosystem, we will have to continue to study the river – like the Red Queen, we have to keep running just to stay in place.

But of course we may want to understand the river better tomorrow than we do today. Throughout the book, I have highlighted important scientific and management questions about the Hudson that we have not yet been able to answer. The combination of a changing ecosystem and important unanswered questions suggests that scientists are not about to run out of important questions about the Hudson to study, and that scientific research on the Hudson will be a worthwhile enterprise for decades to come.

We should use what we know about the river

It goes without saying that all of this scientific understanding won't do us any good (other than delighting scientists) unless we actually apply it to better manage the river. Currently, both government agencies and NGOs concerned with the Hudson are very good in using science to manage the Hudson. The Action

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Agenda of the New York State Department of Environmental Conservation's Hudson River Estuary Program (which guides DEC's actions on the estuary; www.dec.ny.gov/lands/5104.html) has a sound scientific basis. Talented scientists are routinely involved in the committees and subcommittees that produce and evaluate this plan, as well as other management plans for the Hudson. Indeed, one of the pleasures of working on the Hudson over the past 20 years has been seeing the degree to which scientific information is sought and used in management of the river by all interested parties. I know from my colleagues who work elsewhere that science is not always so well integrated into environmental management.

Despite this generally good situation, three issues about the use of science in managing the Hudson are worth mentioning. First, policy and management have lagged behind science in a number of important issues that affect the Hudson, especially on issues that require national or international action, rather than strictly local actions (see the discussion above on climate change and non-native species, for instance). These are hard political problems that will continue to resist easy solution, but should not be dropped. Second, there is a natural tendency to disregard environmental considerations in crisis situations (e.g., storms, failing infrastructure). Crisis planning often results in suboptimal solutions and long-term environmental damage. Although some crises cannot be foreseen or avoided, some "crises" can be avoided by thoughtful, long-term planning, which can avoid these suboptimal solutions and needless environmental damage. We should insist that the long-term perspectives now in place for Hudson River planning continue into the future. Finally, we have seen repeatedly in this country that political winds can shift abruptly, and that science can be ignored or subverted in the service of politics (see Oreskes and Conways' recent book "*Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues From Tobacco Smoke to Global Warming*" for an excellent and appalling account of how this happens). We should not let the present good use of scientific information on the Hudson lull us into thinking that all is well and always will be well. As joint custodians of the Hudson and the resources that it contains, we need always to take care that it is managed wisely for us and for future generations.

THINGS TO SEE AND DO

- Get out your own crystal ball and think about the changes that are likely to occur in and around the Hudson River as a result of changes in the natural environment and human activities and institutions. How will these things affect the river? Are we well poised to manage these changes?
- Write down your predictions and leave them in a time capsule to amaze (or amuse) your descendants 50 years from now.

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