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Feature
From the National Academies

Integrating Policy and Decision Making into Undergraduate Science Education

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INTRODUCTION

> *Scientists gathered in Mill Valley [CA] Thursday as part of a fact-finding mission to determine what effect the Drakes Bay Oyster Co. has on the ecology of Drakes Estero. The company's lease allowing it to grow and harvest oysters in Drakes Estero ends in 2012, and the Point Reyes National Seashore wants to turn it into a wilderness area thereafter. But owner Kevin Lunny said the operation causes no harm and may help the ecosystem. He wants to stay.*
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> *The National Research Council—an arm of the National Academy of Sciences—was tapped by the National Park Service to examine the issue at the request of Sen. Dianne Feinstein, D.-Calif. That process began Thursday as the nine members of the committee—including experts in agriculture, disease, marine sciences and oceanography—heard from a variety of people connected to the issue in what had the feel of a courtroom at the Aqua Hotel . . .*
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> Excerpted from Prado, 2008.

> *"There is no end of examples of policies that have been established at the state level that have failed dramatically because they have not taken into account science and technology issues."*
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> Richard Atkinson, President Emeritus, University of California. In National Academy of Science, National Academy of Engineering, and Institute of Medicine [NAS, NAE, IOM], 2008, p. 2.

The above-mentioned quotes offer important messages and frameworks for readers of *CBE—Life Sciences Education*. First, the need for and impact of science and solid scientific evidence can be found in virtually all aspects of life. Second, science can and should inform policy and decision making to a much greater extent than is currently the case. Third, the science that we teach and ask our students to learn can be infused with real-life examples of policy issues that can help many more students, whether they plan to go on to careers in science or not, to understand science in context. Fourth, although Atkinson's statement notes that many policies have failed because they have not been infused with scientific and technological information and perspective, the majority of people who are elected or appointed as policy makers have taken college-level science courses. However, too many of them have not been prepared adequately to deal with the implications of science in policy and decision making. Even those policy makers who may be steeped in the content of a particular science discipline (i.e., science majors) may not have been asked to understand or explore deeply the processes, nature, and limits of science in decision making.

It is clear that most students who graduate from college will not enter the public policy arena as part of their careers. Still, too many of them leave school without making the connections about how scientific and technological concepts relate to a myriad of issues that affect their daily lives. These include their health and the well-being of themselves and their families, and their roles and responsibilities as citizens of their local community, their nation, and an increasingly interconnected, interdependent, and scientifically driven world. Because the majority of undergraduates do not enroll in science courses beyond the introductory level, infusing these kinds of ideas and perspectives into those courses is especially important (e.g., National Research Council [NRC], 1999; Labov, 2004; Jurkowski *et al*., 2007). Doing so can improve the course at several levels, increasing student participation, enthusiasm, and knowledge retention, as discussed in the fall issue of *CBE−Life Sciences Education* (Chamany *et al*., 2008).

A workshop that the National Academies convened in 2007 focused on the problems in using science and technology information to guide public policy and decision making at the state level. Today, state leaders are responsible for an increasing number of decisions that rely on access to high-quality scientific information—from creating their state's technology portfolio, to managing water and other resources, maintaining critical infrastructure, and improving education and health care. The workshop brought together state leaders with the many sources of

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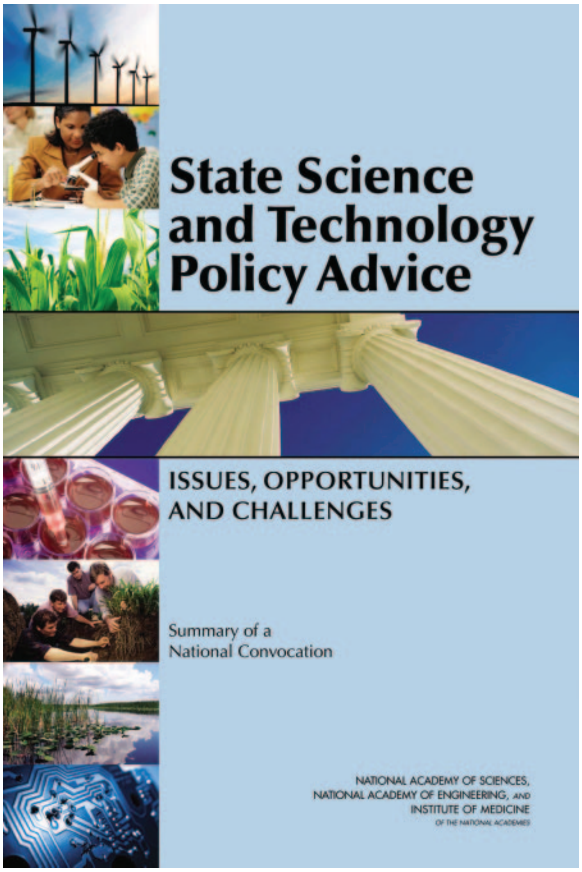

Figure 1. Cover of NAS, NAE, IOM (2008) summary of the national convocation on state science and technology policy advice.

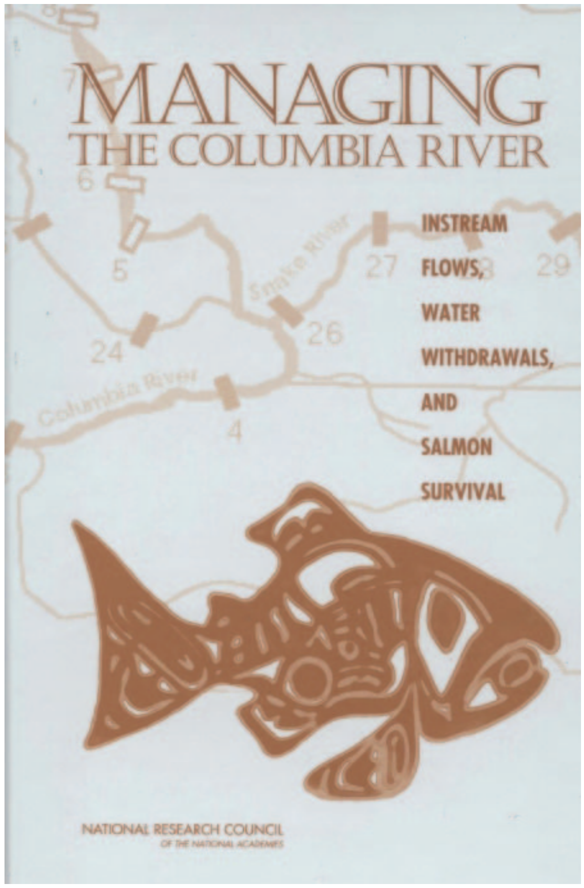

Figure 2. Cover of NRC (2004a) report on Managing the Columbia River.

science advice (NAS, NAE, IOM, 2008[1]; the cover of this report is displayed in Figure 1.) The workshop pointed both to the need for decision makers to pay more attention to science guidance and for scientists to improve the content and timing of their communications.

THE WASHINGTON STATE STORY

At the October 2007 convocation (NAS, NAE, IOM, 2008), Gerry O'Keefe, Columbia River policy coordinator for the state of Washington's Department of Ecology, provided an excellent example of one state's struggle to get and use science advice to break through a decision-making impasse in how to manage the precious water resources of the Columbia River Basin (NRC, 2004a; Figure 2). The details of this case that are presented below are excerpted and modified from the report from that convocation.

The Columbia River carries 200 million acre-feet of water in an average year (which, coincidentally, is about the same size as the water budget for the state of California, O'Keefe noted). It drains an area of 273,000 square miles that extends from Canada to Wyoming and Utah. It is a tightly controlled system that is managed for flood control, agriculture, power generation, and for protection of the salmon that live and spawn in the river, which have iconic value to the people of Washington state. Factors affecting the river are undergoing profound changes, O'Keefe pointed out. Population growth is increasing the demands being made on the river. Climate change, particularly as it affects mountain snowpacks, could alter the amount of water that the river can supply. Salmon species in the river are in decline.

However, the river continues to offer untapped potential for economic development. According to one calculation, withdrawing just 1 million acre-feet of water, which is about half of 1% of the river's annual flow, and applying it to the land would create 18,000 jobs and annual revenues of approximately $850 million. "This is a number that is not ever ignored by the governor's office—or the state legislature," said O'Keefe. "It captures and crystallizes their attention like almost nothing else will."

[1] These three organizations plus the NRC comprise the National Academies, a private, nonprofit organization whose charter is to assist the federal government and the American people in analyzing pressing science and technology policy issues. The NRC serves as the operating and research arm. Much of the work of the National Academies is performed by leading scientists, mathematicians, engineers, social scientists, and policy experts who provide pro bono service to the National Academies and the nation. More information about the National Academies is available at http://nationalacademies.org.

For decades, the state has struggled to develop policies to manage the Columbia River Basin. Many groups have conflicting interests in the Columbia River, including farmers, manufacturers, other private interests, the federal government, the environmental community, and 13 Native American tribes that rely on the river's water. As discussions among these groups deteriorated over the years, management decisions became increasingly difficult. "When state officials or others in charge of mediating among the sides tried to arrange meetings, the sides would not even agree to talk unless they knew what the outcome of the discussion was likely to be." Different groups "have veto power," said O'Keefe. "The federal statute is designed with overlapping authorities and jurisdictions, and unless you have something close to consensus, you're going to find out that you're unable to act."

In 2002, the state turned to the Water Science and Technology Board at the NRC[2] for help. The first task was to define the question to be addressed. "We spent a tremendous amount of time and energy thinking about what it was we were going to ask the National Academy of Sciences [NRC] to resolve for us." The actual charge covered most of two pages, but it can be boiled down to a relatively simple question: If 1 million acre-feet of water were to be removed from the river, what impact would that action have on endangered species, and what could be done to mitigate those impacts? The state did not know what the response from the NRC committee would be, and the final report (NRC, 2004a) did not deliver the answer that the state expected, according to O'Keefe. Although state officials expected that a relatively small withdrawal of water from the river was unlikely to have a measurable effect on the salmon, the NRC report said otherwise. Instead, the committee concluded that salmon populations were in trouble, especially during summers when the flow of the river is lower and the water is warmer. The conclusion of the report, said O'Keefe, was that "you need to be very careful as you allocate water out of the stream. You are getting yourself into a situation where you could end up with a year or a series of years where you have lost your management flexibility and you have in fact predetermined that you will lose your species as well."

Once the report was delivered, policy makers in Washington state had to decide what to do with the NRC's advice. This was not a foregone conclusion, said O'Keefe. State legislators "really are representative of the communities that elect them. They come from all kinds of backgrounds . . . Our challenge is to try to find ways to . . . connect with those people who have the ability to make those decisions." To their credit, despite the many other competing pressures exerted on them, the state's policy makers did not ignore the advice. "We tried, to the extent we could, to be guided by the National Academies to create a flexible and responsive policy framework on the fly that helped us break through the policy gridlock that we had experienced as a state."

State officials opted to look at additional storage developments for Columbia River water and at the use of existing storage facilities. Of every three quantities of water made newly available through this process, one would be set aside for protection of the salmon. O'Keefe reported that the state linked economic and long-term environmental interests of the state in ways that are very creative, and the result turned out to be quite compelling and powerful. Legislation passed in 2006 authorized the creation of a new water program supported by $200 million of funding to develop water supplies over time. And conversations with officials from Canada and surrounding states were initiated to manage the river more effectively. "The future in Washington state as a result of this conversation is really quite a lot brighter," O'Keefe concluded.

IMPORTANCE OF AND RESOURCES FOR UNDERSTANDING SCIENCE AND POLICY

Introducing public policy concepts and perspectives into science courses may seem daunting to some faculty. Few have been explicitly educated to teach science from such a perspective. However, this is a critical component of a well-rounded science education. Many students, especially nonscience majors, are likely to become more interested in science when they can see the relevance of the subject to other things about which they are interested or even impassioned. And there are increasing numbers of resources to help faculty become better versed in the intersection between science, technology, and public policy and decision making.

For example, over the past 6 yr, the National Science Foundation has supported (through its SENCER[3] initiative) the development of 37 model undergraduate courses that explicitly connect science, technology, engineering, and mathematics with "capacious" questions related to public policy and civic engagement. Many of these courses have a local- or state-level focus. A list of these model courses and links to their descriptions is available at www.sencer.net/Resources/models.cfm.

Similarly, the recently published *Pathways to Scientific Teaching* (Ebert-May and Hodder, 2008) takes articles about ecology published over the years through the Ecological Society of America and helps faculty "translate" them into various kinds of exercises for use in undergraduate classrooms and laboratories. Ebert-May and Hodder (2008) builds on *Scientific Teaching* (Handelsman *et al*., 2004, 2007), which offers faculty concrete and evidence-based methods for incorporating research principles into undergraduate courses.

As described above, the National Academies also can serve as a rich source of resources for engaging students in the intersections between science, technology, and public policy. As noted in the first quote, study committees from the Academies' NRC are asked to examine some of the most difficult policy questions facing society today and to inform Congress, federal and state departments and agencies, and others how scientific and technological evidence can contribute to the development and implementation of policy based on what is currently known.

[2] Additional information about the Water Science and Technology Board is available at http://dels.nas.edu/wstb/.

[3] SENCER: Science Education through New Civic Engagements and Responsibilities. Additional information about SENCER is available at www.sencer.net.

Equally important, Academy committees also help inform their sponsors and broader audiences about what is *not* currently known or well understood. Students may be inspired by the challenge of addressing ongoing issues by developing the scientific context.

Below, we provide several brief synopses of reports that various committees of the NRC have authored for use by states that also could provide compelling examples to students about how science contributes to knowledge and decision making. The National Academies also have worked hard in recent years to develop a variety of products that are derived from our reports that could serve as useful supplements to undergraduate courses in biology and related disciplines; we also discuss how to access these resources.

Assessing the Safety of a Biocontainment Lab in Boston

At the request of the state of Massachusetts, the NRC reviewed a draft document from the National Institutes of Health (NIH) assessing the risks of a new National Emerging Infectious Diseases Laboratory being built at Boston University. The facility would include a Biosafety Level 4 laboratory for research on deadly pathogens such as the Ebola virus. The opening of the lab had been challenged through both state and federal lawsuits.

The committee report, *Technical Input on the National Institutes of Health's Draft Supplementary Risk Assessments for the National Emerging Infectious Diseases Laboratory, Boston University* (NRC, 2007a) concluded that the NIH draft risk assessment report has serious weaknesses and does not adequately identify, or thoroughly develop, worst case scenarios for the release and spread of a pathogen. The report commends the NIH for working with the community to identify pathogens to include in the scenarios, but finds that the process seems to have led to the selection of pathogens that do not fully address matters raised by the state. The report concludes that NIH should have included agents that are readily transmissible and would have demonstrated that the modeling approach used recognizes biological complexities, reflecting what is known about disease outbreaks and being appropriately sensitive to population density, for example. This report raises many issues of interest for anyone teaching a microbiology course, particularly a lab course, as well as addressing interesting issues in public health.

Oysters in the Chesapeake Bay

Long before the Drakes Bay Oyster dispute that was mentioned at the beginning of this article, the states of Maryland and Virginia faced their own oyster problem. Decades of heavy fishing, environmental pressures, and deadly disease have nearly eradicated native oysters in the Chesapeake Bay and a once-thriving oyster industry. Because oysters feed on algae, their disappearance is thought to play a role in the general decline of water quality in the Bay, which often becomes algae-laden during parts of the year. At the request of the Maryland and Virginia and federal partner agencies, the National Academies identified potential risks and benefits of introducing the Asian suminoe oyster to supplement or replace the disease-plagued native species. Opponents feared that the nonnative species could become invasive, with potentially devastating impacts on the ecology and economic vitality of the region.

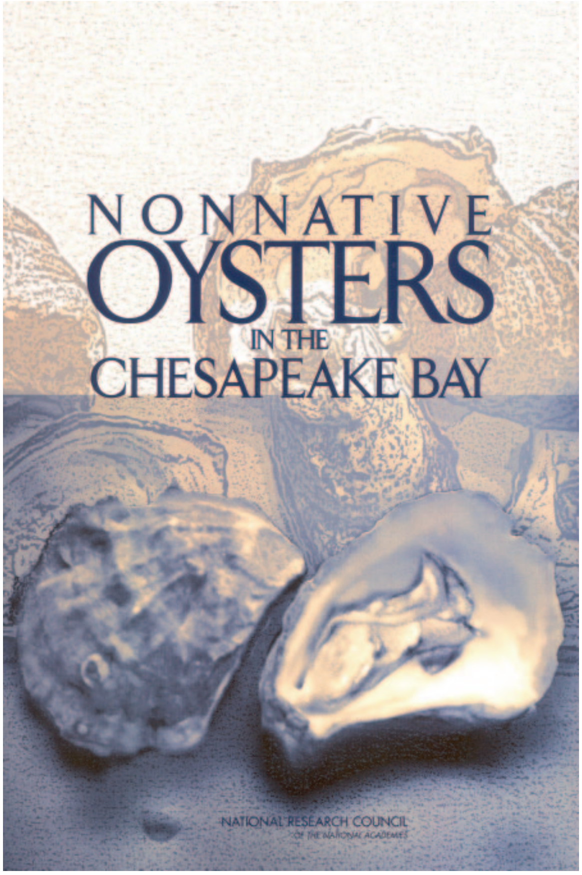

Figure 3. Cover of NRC (2004b) report on the Chesapeake Bay oyster proposal.

Nonnative Oysters in the Chesapeake Bay (NRC, 2004b; Figure 3) recommends aquaculture of nonreproductive suminoe oysters as the most prudent option until completion of research to investigate the potential impacts of introducing this nonnative oyster species. The report also proposes stricter regulations to reduce the risk of unintentional introductions of nonnative species. These issues are relevant for courses in ecology at any level.

Guiding Stem Cell Research in California

In 2004, the State of California sought advice from the National Academies about how to create major new programs that voters had approved for state-funded stem cell research. To help guide the state in its research planning, the National Academies convened experts in the field for a 2-day workshop in California. Topics discussed at the workshop included grant-making processes, intellectual property, institutional review boards, facility development, and the development of standards and ethical

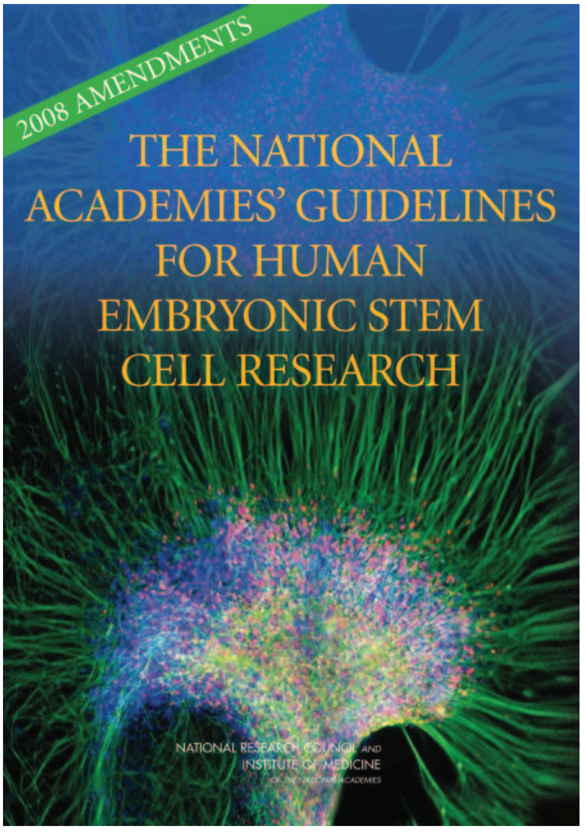

Figure 4. Cover of NRC (2008) guidelines for human embryonic stem cell research.

guidelines. The ethical standards discussed at the workshop were the result of other work the Academies were doing at the time to develop its *Guidelines for Human Embryonic Stem Cell Research* (NRC, 2005). This report recommended the establishment of an oversight system for human embryonic stem cell research that has been widely adopted nationwide. The original report has since been updated twice (NRC 2007b, 2008; see also Figure 4). Asking students to view the progression of these guidelines can offer great insight into the rapid progress of cutting-edge science and its implications for public policy and welfare. The basic science underlying this topic derives from studies in developmental biology, cell biology, and gene regulation, and can be approached from a relatively simple or a very sophisticated level of instruction.

Watershed Solutions in New York

The state of New York had always enjoyed high-quality water from the Catskill Mountain watershed, which provides ~90% of the drinking water for New York City. Unfortunately, increased numbers of housing developments and associated septic systems, and the impacts of agriculture, have caused water quality to deteriorate. By the late 1990s, New York City water managers had two choices: build a water filtration system at an estimated cost of up to $6 billion or take steps to protect its major watershed.

To help weigh the scientific and technical aspects of its dilemma, the state turned to the National Academies. On the basis of recommendations in *Watershed Management for Potable Water Supply: Addressing the New York City Strategy* (NRC, 2000), stakeholders decided against building the filtration system and began taking recommended steps to protect the watershed at a total projected investment of ~$1–1.5 billion. Water use and quality is, of course, a central topic for any course on natural resources or sustainability and can be introduced in courses on microbiology, public health, and ecology.

ACCESSING NATIONAL ACADEMIES RESOURCES

Readers may access information about National Academies studies in various ways. Information about all studies in progress can be searched through the Academies' Current Projects System.[4]

Additional information about current projects and completed projects can be obtained by entering keywords into the search engine or by selecting a general disciplinary area located on the left side of the National Academies' home page.[5] Each of the disciplinary divisions within the Academy have worked hard over the past 10 years to make findings from their reports accessible to broader audiences through a series of derivative products. For example, a listing of an extensive series of such resources in the earth and life sciences can be found at http://dels.nas.edu/dels/sp_products.shtml.

The National Academies Press provides several ways to search for Academies' reports and related information.[6] A very sensitive search engine allows users to enter parts of the title of a report or key words to locate all reports that the Academies have published on this topic. This website also contains several other features that readers can use to find information:

- After a particular report has been located, readers can use the Web Search Builder tool to use key words or phrases from that book to search for information within that book, across the academies' collection of resources, or across the Web.
- The Reference Finder allows readers to paste in their own text to find books that are related to the topic. For example, a sentence containing key words or phrases from a journal article or even from a student's draft term paper can be entered to search for additional information.

We hope that these examples are illustrative. Resources are available as described above and through many other sources (see Chamany *et al.*, 2008). Opportunities to make science and technology more relevant to many more students await!

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[4] Available at www8.nationalacademies.org/cp.
[5] Available at http://nationalacademies.org.
[6] Available at http://nap.edu.

REFERENCES

Chamany, K., Allen, D., and Tanner, K. (2008). Making biology learning relevant to students: integrating people, history, and context into college biology teaching. CBE Life Sci. Educ. *7*, 267–278. http://www.lifescied.org/cgi/reprint/7/3/267 (accessed 14 October 2008).

Ebert-May, D., and Hodder, J. (eds.) (2008). Pathways to Scientific Teaching, Sunderland, MA: Sinauer Associates, Inc.

Handelsman, J. *et al*. (2004). Scientific teaching. Science *30*, 521–522. http://www.sciencemag.org/cgi/content/full/304/5670/521?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=handelsman&searchid=1109276347970_1405&stored_search=&FIRSTINDEX=0 (accessed 14 October 2008).

Handelsman, J., Miller, S., and Pfund, C. (2007). Scientific Teaching, New York: W.H. Freeman and Company.

Jurkowski, A., Reid, A. H., and Labov, J. B. (2007). Metagenomics: a call for bringing a new science into the classroom (while it's still new). CBE Life Sci. Educ. *6*, 260–265. www.lifescied.org/cgi/content/full/6/4/260?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=1&author1=labov&andorexacttitle=and&andorexacttitleabs=and&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&resourcetype=HWCIT,HWELTR (accessed 14 October 2008).

Labov, J. B. (2004). From the National Academies: the challenges and opportunities for improving undergraduate science education through introductory courses. Cell Biol. Educ. *3*, 212–214. www.lifescied.org/cgi/content/full/3/4/212?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=1&author1=labov&andorexacttitle=and&andorexacttitleabs=and&andorexactfulltext=and&searchid=1&FIRSTINDEX=10&sortspec=relevance&resourcetype=HWCIT,HWELTR (accessed 14 October 2008).

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (NAS, NAE, IOM). 2008. State Science and Technology Policy Advice: Issues, Opportunities, and Challenges. Washington, DC: National Academies Press. www.nap.edu/catalog.php?record_id=12160 (accessed 14 October 2008).

National Research Council (NRC). 1999. Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology, Washington, DC: National Academies Press. http://nap.edu/catalog/6453.html (accessed 14 October 2008).

NRC. 2000. Watershed Management for Potable Water Supply: Addressing the New York City Strategy, Washington, DC: National Academies Press. www.nap.edu/catalog.php?record_id=9677 (accessed 14 October 2008).

NRC. 2004a. Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival, Washington, DC: National Academies Press. www.nap.edu/catalog.php?record_id=10962 (accessed 14 October 2008).

NRC. 2004b. Nonnative oysters in the Chesapeake Bay, Washington DC: National Academies Press. www.nap.edu/catalog.php?record_id=10796 (accessed 14 October 2008).

NRC. 2005. Guidelines for Human Embryonic Stem Cell Research, Washington DC: National Academies Press. www.nap.edu/catalog.php?record_id=11278#description (accessed 14 October 2008).

NRC. 2007a. Technical Input on the National Institutes of Health's Draft Supplementary Risk Assessments and Site Suitability Analyses for the National Emerging Infections Diseases Laboratory, Boston, University: A Letter Report. Washington, DC: National Academies Press. www.nap.edu/catalog.php?record_id=12073 (accessed 14 October 2008).

NRC. 2007b. 2007 Amendments to the National Academies' Guidelines for Embryonic Stem Cell Research, Washington DC: National Academies Press. www.nap.edu/catalog.php?record_id=11871 (accessed 14 October 2008).

NRC. 2008. 2008 Amendments to the National Academies' Guidelines for Embryonic Stem Cell Research, Washington DC: National Academies Press. www.nap.edu/catalog.php?record_id=12260 (accessed 14 October 2008).

Prado, M. 2008. Impact of oyster harvest at Drakes Estero studied. *Marin Independent Journal*, September 4. www.marinij.com/marinnews/ci_10382590?IADID = Search-www.marinij.com-www.marinij.com (accessed 14 October 2008).