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The Path to Sustainable Water Resources Solutions

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The Path to Sustainable Water Resources Solutions

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Water is essential both to human survival and to the ecosystems on which people depend. Although Maine is blessed with abundant water sources, managing them is crucial for both short and long-term uses. John Peckenham and his co-authors describe the varying time and spatial scales involved in managing water resources, pointing out that policy decisions made at one time can have far-reaching consequences. They provide illustrations of water-resource projects from Maine's Sustainability Solutions Initiative, ranging in size from Sebago Lake to vernal pools on individual properties.

High quality water is more than the dream of the conservationists, more than a political slogan; high quality water, in the right quantity at the right place at the right time, is essential to health, recreation, and economic growth.

EDMUND S. MUSKIE,
U.S. Senator, speech, March 1. 1966

INTRODUCTION

It is difficult to imagine the state of Maine without also envisioning its waters. Unlike some other regions across the globe, Maine is rich in rivers, lakes, streams, and wetlands. These water resources not only help to define the state's character, but also fill many valuable roles for the people of Maine. Water gives us sustenance, slakes our thirst, powers our homes and industries, and instills a sense of tranquility. Water resources are important to Maine's economy, and lakes alone have a net economic value that is greater than $6 billion (Boyle, Scheutz and Kahl 1997). Today, and far into the future, we rely on these water resources to continue to provide all of these services undefiled and undiminished (Brookings 2006). Water is like the blood in our veins: constantly moving to perform the many tasks that sustain us and our communities. Water's role is fundamental in sustainability science because it is essential for both human beings and the natural ecosystems that sustain them.

The character and form of water resources are a result of the complex interplay of geologic, climatic, and human factors, much of which have occurred just in the past 12,000 years. Geological formations provide the underlying structure of the land made up of granite and schist that may in turn be covered with sand or clay. Living nature drapes this base with forests and meadows, and human beings alter the land for farms and towns. Climate controls the timing and amount of moisture delivered by weather systems. Maine's weather is famously variable, yet the landscape receives precipitation throughout the year. The state's dynamic climate includes plentiful rain and snow, along with temperatures that can range from well below freezing to the high eighties each year. Most years have ample water that flows over and under the land surface and ultimately returns to the sea. Maine has an extraordinary number of high-value permanent waters in the form of lakes, rivers, and streams. There also are transient waters such as vernal pools, springtime boggy areas, which serve important hydrological and ecological functions.

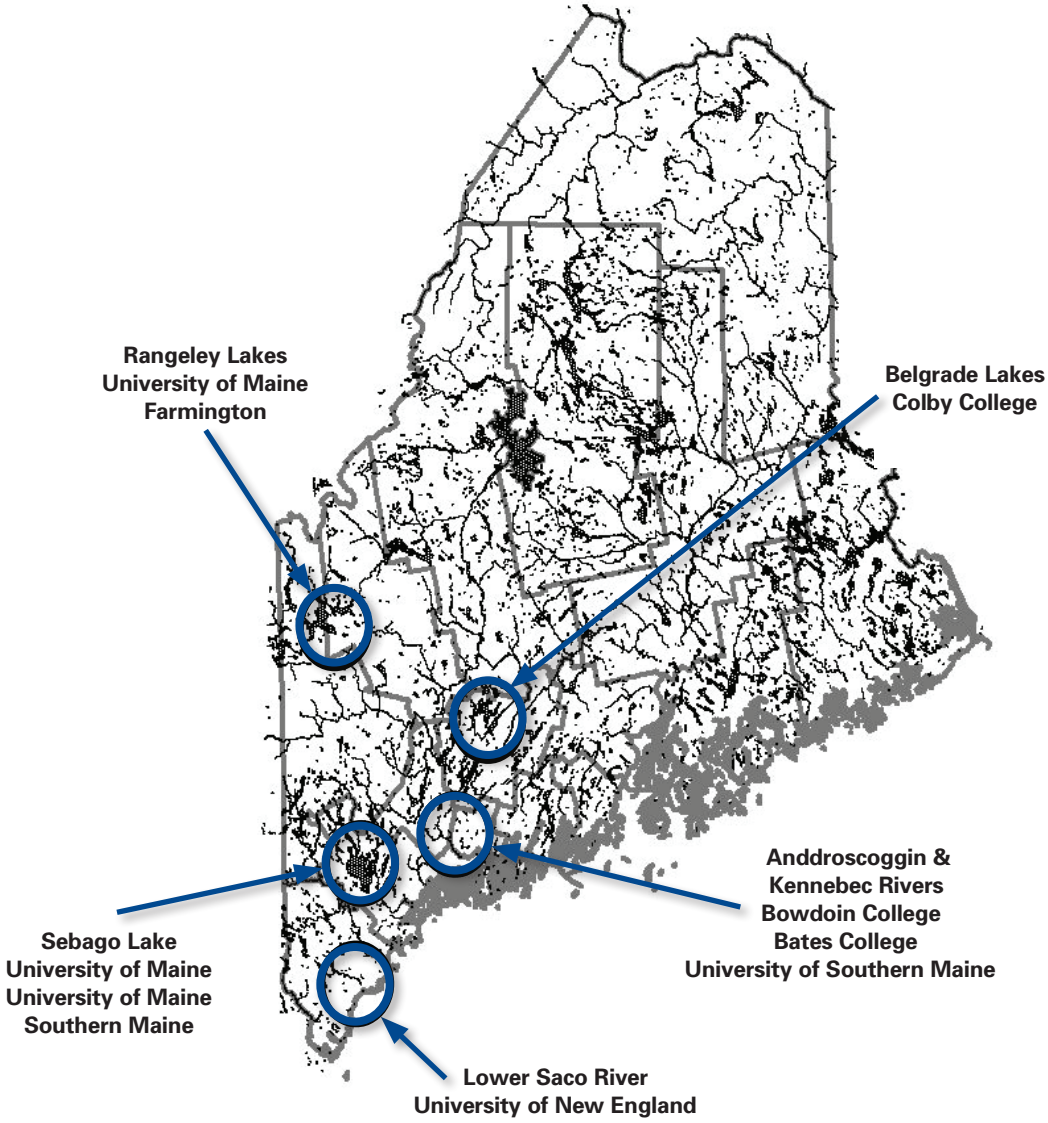
Water's role is fundamental in sustainability science because it is essential for both human beings and the natural ecosystems that sustain them.

Maine's Sustainability Solutions Initiative (SSI) is a federally funded statewide initiative being implemented in Maine through the Senator George J. Mitchell Center at the University of Maine. SSI researchers pursue their work through collaborative partnerships with citizen groups, community and municipal officials, state and federal agencies, and the private sector. Given the inextricable links between Maine's people and its vibrant landscape, SSI researchers approach each place-based research endeavor with broad partnerships that recognize past, current, and emerging social, cultural, and economic perspectives.

One SSI objective is to investigate the nature and scale of human dependence and impacts on water resources, which is the focus of this paper. The projects described here seek to understand how people can strike the balance between maintaining natural water systems and pursuing societal needs. People have long benefited from Maine's waters via transportation, fishing, industry, and tourism. One key question to answer is how all of the demands for water's services can be balanced for the benefit of current and future generations (Chapin, Kofinas and Folke 2009). Progress toward these answers is currently emerging from a broad dialogue between researchers and stakeholders.

The foundation for water-resources management goes back to ancient civilizations. Management of water resource is not simple and requires an understanding of the complexities of natural systems, population growth, and demand for a diversity of uses (NRC 2004). None of this work would be possible without the firm foundation that has been built by science and

FIGURE 1: **Location of SSI Water Projects in Maine** [(a)]



[(a)] Vernal pool study areas are found across the state. Base map shows the major rivers and lakes of Maine.

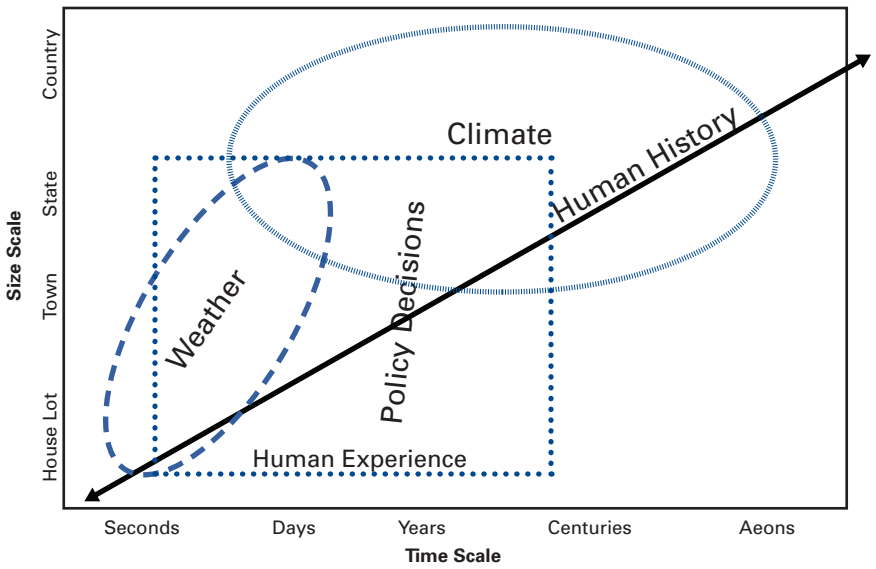
natural-resource agencies involved with water resources, such as the U.S. Geological Survey (hydrology), National Weather Service (weather and climate), and the Maine Department of Environmental Protection (natural-resource management). There is also a long tradition of water research by faculty and students at the campuses of the University of Maine System and by Maine's private colleges and universities. The support of and collaboration with these agencies and the private sector are essential to the long-term success of SSI. Figure 1 shows some of the partner academic institutions that are currently working on an SSI project focused primarily on water resources.

APPROACH

Experience suggests that effective approaches to water-resource management and stewardship in the real world require more than a set of rules to guide actions. Applying a one-size-fits-all formula is a poor solution to many problems. The SSI's research strategy recognizes that solutions needed by society must come from a process that has participation from a broad set of stakeholders, each of whom has interests and expert knowledge to contribute. Such an approach is well-suited to variable conditions and affords flexibility to revise and update solutions-oriented work. This approach, while promising, presupposes effective communication and effective methods to exchange and tailor technical knowledge. To this end, SSI projects place emphasis on understanding and communicating complex issues, including both technical scientific knowledge and stakeholder knowledge.

The process uses models in different forms as tools for analysis, understanding, and communication. When it comes to defining problems and finding solutions,

FIGURE 2: **Physical Dimensions of Water Resource Drivers**

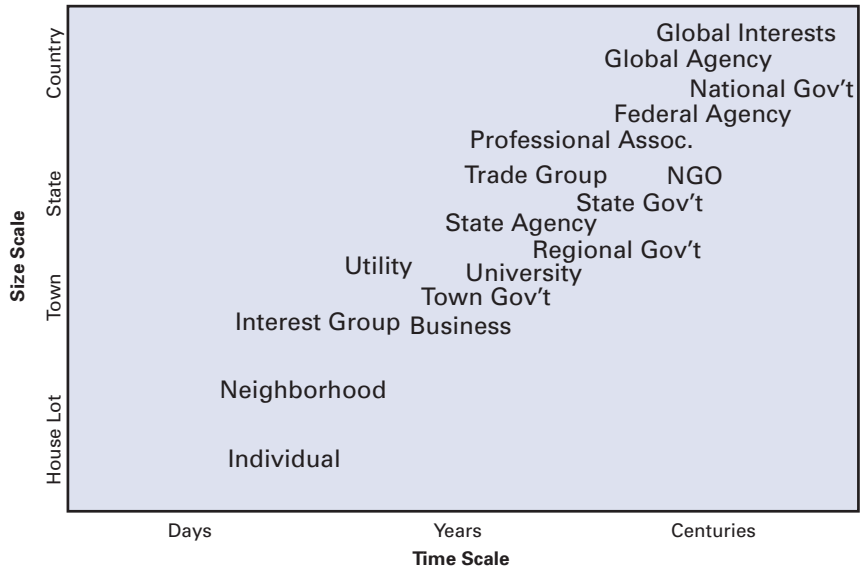


models show complex relationships and how things relate to one another. If people want to know how decisions affect conditions in the future, models can be used to show future conditions. Specialized maps are a type of model that show both reality and the potential shape of future conditions, for example, how the size of lakes would change if average rainfall increased by 25 percent. Models can also follow rules to describe how different environmental factors affect one another, such as how temperature and rainfall affect the growth of different trees. The rules used in models may appear as mathematical equations that relate rainfall to water level, or they may be qualitative, expressing the personal preferences of stakeholders. Models can help us to visualize issues of concern and locate pathways to solutions. In terms of understanding the size of some problems, teams use maps to model the physical and human dimensions of questions about water resources. (See article by Waring, this issue, for more detailed discussion of models.)

Water resources have unique associations across scales of time and location (Figures 2 and 3). Figure 2 shows the scales of natural features such as weather and climate, along with the limits of human experience, human history (collective memory), and policy decision making. The scales used are time on the horizontal axis and size on the vertical. Although the process of forming policy may take a relatively short time, the consequences may reach far into the future. Weather operates on a time scale of seconds to days and covers microscopic areas up to regions the size of New England. Climate naturally covers a larger region and a time period of centuries or longer. Climate and geology interact to shape the land's surface. Individual human experience (dotted box, Figure 2) overlaps weather and climate and contributes to human history. Policy decisions may start by occupying a narrow zone in time and space that is constrained by how governmental institutions function. However, after the decision-making process is completed, some policies have broad and long-lasting effects. One example of this is the Clean Water Act, which continues to improve the quality of surface waters across the country decades after the policy was instituted. Problems and solutions may be found anywhere. For example, a chemical spill can cause localized contamination that may not persist for long, whereas in contrast, mercury deposition affects all of Maine and the consequences will be seen in ecosystems for many decades.

Competing human demands have different scales and importance that must be incorporated into solutions. Figure 3 represents some of the human dimensions that SSI addresses. Here, the scales represent the complexity of social organizations on the horizontal axis and number of people affected on the vertical. Organizations are loosely defined to include everything from informal groups of individuals to formal businesses and governments (Scott 2008). This diagram illustrates variations in the scale of the decision-making process involving people and resources in different organizations, based on the number of people involved and the reach of a given organization. Such depictions help to explain how people and communities might be affected by an area of intersecting demands. Are the primary stakeholders who have interests in a particular problem neighbors, a town, a state agency, or a mix? Relationships may determine the scales of the issue and identify the appropriate scales for desired solutions. Scale helps to determine who should be part of the solution-finding process, from individuals to national government.

FIGURE 3: **Human Dimensions of Water Resource Issues**



There are other dimensions we do not depict, which should also be considered, including economic well-being, community values, and how individuals understand the context of the problem. It is our goal to find answers to these complex and interwoven questions using this kind of figure to drive the inquiry, seek the root causes of conflict, and derive solutions.

The SSI process links knowledge with action via communication, collaboration, effective implementation of policies, and other engagement processes (McNie 2007; Hage, Leroy and Petersen 2010). Some key aspects of this approach involve forming partnerships with diverse interests and agreeing to goals that are necessary, reasonable, rational, and practical. What is the issue of concern, what tools are needed to characterize the situation, what will happen as an outcome, and can the outcome (solution) work? Conceptual models are used as tools to define problem boundaries and to identify stakeholders who may be missing, neglected, or silent.

In the specific area of water resources, the problems and solutions often change in response to human expectations and needs and uncertain changes in natural systems. Human landscapes change over time and affect water resources. Land use in Maine during the 19th century led to deforestation that caused increased delivery of sediment to many rivers, lakes, and coastal regions (Eves 1992). The natural landscape continues to change in response to weather and climate. Natural forces such as climate are known to vary over long time periods. Over shorter time periods, extreme weather events such as floods or droughts have detrimental effects on people and places. Water-resources problems and solutions become hard to discern because the systems that drive the delivery of water constantly interact with human modifications of the landscape. For example, heavy rain in a city will cause flooding because the natural drainage has been lost and rainwater is diverted to now inadequate drain systems. Considering all of the pieces at once, making decisions for something as apparently simple as maintaining the water level in a lake used for water supply, hydropower, and recreation becomes very complex. Decisions about how much water should be held back by an impoundment, how much should always be flowing downstream, and how much flooding can be tolerated along the shore have connections and consequences to many different people and things. The SSI process helps stakeholders to integrate new knowledge of the complex workings of the natural system with human needs and actions to make decisions that lead to desired lasting effects.

People tend to remember and recognize patterns learned through observation. However, our memory can sometimes play tricks on us: were winters really colder and snowier when we were six years old? The underlying forces that shape the natural world work on scales that can range from obvious to too subtle to detect. In general, the memory from human experience may be limited in time (generations) and location (hometown). Patterns of variation in water resources in time and space (Figure 2) exceed the limits of what we would consider to be human experience. This means that as individuals, it is not easy to comprehend the dynamic roles of water in the landscape based only on personal experience and observations. For example, few of us have experienced a massive flood or multiple-year drought, but we may understand that they occur on

average once or twice a century. Pathways to solutions need to accommodate human experience while providing credible and trustable new knowledge. People are used to things as they are, even if the current condition is actually a long-forgotten alteration of the natural landscape. These alterations have consequences that an individual may accept as the present-day natural condition. Past human actions, such a building a dam, could have consequences that do not become apparent for decades.

In practice, all the variables in a given problem are not apparent, and the solution may not be visible immediately. That is why we need a method to test what will happen given appropriate scales of time and space. Concepts of scale are used by SSI teams to focus on problems involving water resources that are important to people today and where action will be capable of producing results within the span of human experience. A challenge is how to get acceptance for a solution that has greater value at some future time. Sustainability science research seeks to yield actions that provide both a present-day and a future benefit.

WATER-RESOURCES PROJECTS

The SSI has a number of projects that focus on managing water resources, and several others connected to water resources but in which it is not a central focus. The water-resources projects underway address problems on different human (individual or organizational), time, and space scales. To illustrate this concept, Table 1 shows some of these within the dimensions relevant to human decision making. The projects shown cross over many scales that link diverse stakeholders. We describe three here that are associated with complex water-resource issues: Sebago Lake; the Belgrade Lakes; and vernal pools. The lower Saco River basin project is shown in the sidebar.

Sebago Lake

The Sebago Lake watershed is 361 square miles and overlaps numerous towns from Portland to Bethel. Sebago Lake provides drinking water to approximately 200,000 Greater Portland residents, along with hydropower and recreational opportunities. The SSI Sebago Lake team is working in collaboration with two entities with a significant investment in managing the lake, the Portland Water District and South African Pulp and Paper, Inc. (SAPPI), along with the Maine Department of Environmental Protection, Lakes Environmental Association, and Friends of Sebago Lake.

The Sebago Lake region exemplifies the complexity of entwined social-ecological systems. The character of the lake is vulnerable to the effects of urbanization, changes in forestland management, and a changing climate. An impressive range of links between the lake and people are evident from the lake's ecology, its year-round recreational use, and use for hydroelectric power generation and as a water supply. A primary focus of the community of lake users and stewards is lake level. Underlying this issue are the economic benefits derived from hydropower generation, the convenient boating experience afforded by higher lake levels, potential degradation of water quality from erosion with higher lake levels, and loss of lake frontage due to high lake levels. The sheer size of the watershed means that fully integrated control of the biological or physical aspects of the lake is beyond the ability of any one stakeholder. For example, the outlet dam can be used to store or release only a small fraction of the water stored in the lake. As a consequence, adjusting lake levels using the outlet dam is in the control of the hydropower interests. However, the timing and amount of water going into the lake is mainly controlled by annual weather patterns and the connections between Sebago Lake and its sub-watersheds. If SSI research data support the supposition that weather and climate are the factors that most strongly affect lake levels, then solutions will need to focus more on having a plan to react to specific weather conditions, rather than agreements or rules to maintain an absolute lake level via the outlet dam.

In…water resources, the problems and solutions often change in response to human expectations and needs and uncertain changes in natural systems.

TABLE 1: **Scales of SSI Water-Resources Projects**

Focus Area	Lead SSI Institution	Upper Limit of Spatial Scale	Range of Time Scale	Human Organizations Scale
Sebago Lake	University of Maine	500 km^2	Weeks-Years	Regional-State Entities
Belgrade Lakes	Colby College	100 km^2	Weeks-Years	Individual-Local-Regional-State Entities
Lower Saco River Basin	University of New England	100 km^2	Years-Decades	Individual-Local-Regional Entities
Rangeley Lakes	University of Maine-Farmington	100 km^2	Weeks-Years	Individual-Local-Regional Entities
Coastal Communities	University of Maine	1000 km^2	Years-Decades	Local-Regional Entities
Lower Androscoggin River Basin	Bowdoin College	1000 km^2	Weeks-Decades	Individual-Regional-State Entities
Vernal Pools	University of Maine	0.01 km^2	Weeks-Years	Individual-Regional-State Entities

Belgrade Lakes

The SSI team of researchers at Colby College and the University of Maine-Farmington, along with stakeholders including the Belgrade Conservation Alliance, the Maine Congress of Lake Associations, Maine Lakes Resource Center, five lake association, and several state agencies and towns are focused on the Belgrade Lakes. This project team is particularly focused on understanding the effects of a changing landscape and climate on lake-water quality. The Belgrade Lakes region is an important economic engine in central Maine that includes seven major lakes and 13 communities. The lakes are an important economic and recreational resource to the local communities and are also central in defining community members' sense of place and family history. There is strong stakeholder interest in maintaining lake quality.

The problems and place-based context seen in the Belgrade Lakes region represent a different set of stakeholders and needs than we see at Sebago Lake. In the previous century, invasive fish species were stocked to improve fishing for destination hotels. Not only has the traditional profile of fish species of the lakes been altered, but the lakes themselves have changed. The current shape of the lakes was determined by dams built circa 1850. The Belgrade Lakes SSI team is studying how these and other landscape changes have affected the lakes and whether the quality of the lakes is near a crisis condition caused by phosphorus and other nutrient runoff or invasive species. Related research includes working with individuals and associations to understand how landowners perceive changing water quality and decide whether to use best practices on their property to prevent nutrient runoff. The team is addressing the need for new knowledge to educate stakeholders from individuals and lake associations to entire towns. The overall goal is to inform the decision-making process to derive actions and policies that will sustain lake-water quality. This project is contributing a roadmap to solutions that uses a combination of discovering historical land-use change, analyzing the long-term effects of changing land use on water quality, and assessing the vulnerability of the lakes to change in the future. A solution in this project could be a process that helps individuals to commit to actions that benefit all the other individuals within the region.

Vernal Pools

Vernal pools are particularly difficult to manage because of their small size, widespread distribution, seasonal hydrology, habitat requirements of pool-breeding amphibians, and state law regulating development around "significant" pools. Management must include not only the pool itself, but also the critical habitat surrounding the pool. Adding to this complexity is the fact that vernal pools fall under multiple jurisdictions (federal and state agencies plus local municipalities) with multiple landownership boundaries. The vernal pool team is focused on inproving the management of vernal pools on private land by integrating ecological research on patterns of

Collaborating with Stakeholders to Support an Estuary's Health

By Kim Ridley

The Saco River estuary is running cleaner than it has for decades, due largely to restoration efforts and the closing of textile mills. Fish and birds are returning, people are enjoying recreational opportunities on the estuary, and many in Biddeford and Saco are looking to the river to help to revive the local economy. Now, however, the estuary faces new pressures, including increasing development and population and changes in land use and climate.

Helping local stakeholders to guide a healthy future for the estuary and its surrounding communities is the focus of an SSI project at the University of New England (UNE) led by Pamela Morgan, associate professor in the Department of Environmental Studies, and Christine Feurt, director of the Center for Sustainable Communities.

The UNE researchers are collaborating with scientists from the Wells National Estuarine Research Reserve and local stakeholders to understand how coastal development and other factors affect plants and animals in the estuary. More than 100 bird species have been recorded in the estuary, along with sturgeon and other important fish species and rare plants. The team's findings will identify ecological indicators of the estuary's health that local stakeholders can use to make more informed decisions to support a sustainable future for the region.

A key element of the project is training the next generation of problem solvers by giving UNE undergraduate students opportunities to conduct hands-on research in the field and in the community. As part of an environmental communication course, UNE students worked with faculty to develop a "Sustaining the Saco" workshop, along with other educational events for local community members.

Students and faculty on the team have so far engaged representatives from nearly 40 stakeholder groups, including Saco and Biddeford officials, residents, business owners, and planning board members, along with conservation groups and local and national agencies for workshops, trainings, and community dialogues.

The researchers are gathering stakeholder input each step of the way as they study the ecology and economy of the region, about which little was previously known. After two years of fieldwork, the UNE team has collected valuable data about the estuary and identified key stakeholder concerns, which include water quality; coastal development; curbing invasive species; protecting rare, threatened, and endangered species; and the effects of sea-level rise. "We know much more about what stakeholders value and what they're concerned about, and we're working with them to figure out how to best address these issues," Morgan says.

Both Morgan and Feurt see collaborating with stakeholders as essential to the project's success. "By engaging the people who care for a place with researchers who are willing to direct their studies to answer questions important for land-use policy, conservation, and stewardship, we are developing a model for collaborative research that supports community goals for sustaining local values," Feurt says.

Team Members: Noah Perlut, Stephan Zeeman, Michael Daley, Michelle Steen-Adams, James Sulikowski and Greg Zogg of the University of New England; and Michele Dionne of the Wells National Estuarine Research Reserve.

Project Stakeholders: Saco River Corridor Commission, Maine Department of Environmental Protection, the city of Biddeford, the town of Saco, Saco Valley Land Trust, local residents, Saco River Salmon Club, Southern Maine Regional Planning Commission.

movements and habitat use by amphibians with research on how stakeholders make decisions. The purpose of this research is to understand the perspectives and concerns of landowners that become part of conservation practice to enhance their cooperation in proactive planning.

The vernal pool team and collaborators are studying how vernal pools are affected by activities such as urban

development and forest practices. Private landowners, local governments, developers, and regulators all have interests that must be addressed while complying with state and federal natural-resource-protection regulation. This SSI project will contribute a roadmap to solutions that combines discovering historical changes in land use, analyzing the effects of development and forest management on vernal pools, understanding the economic impact of conservation of vernal pools on landowners and communities, and assessing how the vulnerability of pools affects decisions for local land-use management. As shown in Table 1, the human dimensions for vernal pools are defined by a smaller individual scale compared to lake projects, while the consequences are important at a large statewide scale. Ultimately, individual action (setbacks, zoning restrictions, avoiding fragmentation of the landscape), within constraints imposed by governmental institutions, will drive the cumulative solutions that will sustain vernal pools in the landscape. Solutions in this project will enable communities to better balance economic development with the conservation of natural resources on private land and allow individuals to make decisions about how to manage vernal pools on their land for ecological and land-use goals.

SOLUTIONS

The goal of SSI is to help Maine communities and people to find solutions to urgent problems at the intersection of economic, social, and environmental issues. Ultimately, findings from SSI research projects help communities to make more informed decisions about their future and also contribute to improved public policy. At the same time, SSI aims to advance the emerging field of sustainability science, which seeks to meet the needs of current and future generations without compromising the planet's life-support systems.

Solutions arise from partnerships between diverse stakeholders and researchers who together link knowledge with action (Cash et al. 2003; van Kerkhoff and Lebel 2006) in a two-way exchange. The effectiveness of different knowledge-action strategies varies with the characteristics of the perceived problem or need. SSI works to identify context-dependent best practices for developing durable solutions. Context is important, for example, the role of the Army Corps of Engineers in water resources differs from that of the Federal Energy Regulatory Commission. This is also true of individual stakeholders, governments, and other interested parties.

Projects employ a process in which researchers and stakeholders collectively define a focal point. Sometimes this process can take a project in unanticipated directions. Such interactions ultimately improve communication, build trust, and strengthen collaboration. A good example is a project working with coastal communities, where the solution process illustrates both the flexibility of the SSI approach and the use of new knowledge to solve water-resources problems. The project team initially worked on planning for anticipated future climate-related sea-level rise. The original plan involved coupling social research on knowledge, attitudes, and perceived risks with scientific research to define likely future hydrological states. An important early finding from the social research was that the future risks and uncertainties from gradual increases in sea level were of less immediate concern to communities than the damage caused by the runoff from large storm events. As a result, many coastal communities helped to redirect research towards understanding the needs and requirements to resize culverts to minimize damage to roads and property from excessive storm runoff. This stakeholder-informed programmatic change was viewed by towns as a more important need and desired solution, even though preparing for sea-level change remains a long-term challenge. (See sidebar for a student spotlight related to this project.)

Sometimes the solution involves a public space where diverse stakeholders can gather, learn, and deliberate. One such outcome has been a new building to bring focus on the lakes. The coincidental establishment of the new Maine Lakes Resource Center (dockstodoorways.com) provides a location for regional conservation groups to meet and a venue for researchers to share information about the health of the lakes and other key findings with the public, such as best practices to maintain and restore lake-water quality. The Belgrade Lakes team is taking advantage of this opportunity to get involved in numerous activities ranging from field research experience for undergraduates to water-quality research. The learning center provides a physical focal point to build even more connections with stakeholders.

Other times solutions emerge from new information that contributes to improved public policy and more informed individual and community decision making. For example, SSI's vernal pool project is working with two Maine towns to develop model solutions that allow regulatory flexibility and help communities to plan development in ways that benefit people and wildlife alike. The team's findings will provide data to help communities conserve natural resources, guide development, and reduce uncertainty for landowners. Ultimately, findings will be used to create management policies that address the economic concerns of Maine citizens while conserving significant vernal pools, crucial habitat, and the amphibians and other wildlife that rely on these important places.

Water resources are not just important to the people of Maine. They also sustain the natural resources that form the foundations of the state's economy through forestry, fisheries, tourism, and recreation. Maintaining the form and function of water in Maine's landscape is one of many challenges that must be faced in the 21st century. Just as water moves across the landscape and connects people and places, the solutions approach adopted in SSI joins people and their landscapes in new ways to solve problems that are important today and into the future. In this paper we have presented just some examples of the work currently underway. Each of SSI's water projects has a place-based focus identified by stakeholder needs and a plan for the types of solutions desired. The approaches employed by SSI teams are building long-term relationships that will help continue this work into the future.

ACKNOWLEDGMENTS

This work was supported by National Science Foundation award # EPS-0904155 to Maine EPSCoR at the University of Maine. Numerous individuals, agencies, and organizations have contributed to the SSI projects described. The dedication and hard work of the SSI team and partners across many institutions, corporations, and governments is acknowledged. The accomplishments are many and more details on the breadth of involvement in SSI can be found at www.umaine.edu/sustainabilitysolutions. Special thanks to Jessica Jansujwicz for input on vernal pools and Emily Peckenham for a critical review.

STUDENT SPOTLIGHT

Alexander Gray

Masters Student, Ecology and Environmental Sciences; Graduate Research Assistant, SSI

The Patriot's Day storm of 2007 caused an estimated $45 million in infrastructure damage in Maine communities, according to the U.S. Geological Survey. While such severe storms are uncommon, they are expected to become increasingly frequent and intense due to climate change, and Maine's coastal communities are particularly vulnerable. Alexander Gray is part of a team developing a framework for solutions that will help these communities address their particular challenges in adapting to climate change.

What problem are you working to solve?

Our research focuses on the risks that coastal communities face as climatic conditions change, along with the barriers that make adapting to these changes difficult. We're specifically looking at flooding from extreme storms, which can cause costly damage to local communities. Our team is trying to understand the problems associated with managing storm-water runoff in a changing climate and the local decision-making processes in coastal towns.

Managing storm-water runoff is not a straightforward process. First, using "hard" solutions—making physical infrastructure changes—is expensive. Second, current climate science and models are often too uncertain and broad to be useful to local decision makers. We need to figure out what information people need and will act on in order to drive solutions.

What progress are you making toward solutions?

We've surveyed coastal officials and interviewed stakeholders including county emergency management directors, a regional planning director, a town manager, a town administrator, and Maine Department of Transportation staff to understand how they view the problem of storm-water runoff and how they've been managing it.

We've learned that coastal communities experience different types of damage during storms. For example, in Lincolnville, when heavy rains flood lakefront properties, the town must ask the downstream town of Camden to open a dam to lower water levels. This usually causes flooding in Camden's downtown riverfront buildings, so the town is often reluctant to open the dam. In Portland, downtown flooding is the result of culverts that are too small to handle the runoff from severe storms. The city wants to fix the culverts, but limits of federal assistance further strain limited municipal resources.

Our findings so far have made it clear that solutions need to be based both on the particular problems and the type of community, for instance, a small rural town versus a city. In addition, information to solve these problems needs to be specific to each community in order to support its decision-making process.

How could your findings contribute to a more sustainable future in Maine and beyond?

By studying how coastal communities prepared for, and were affected by, extreme weather like the Patriot's Day storm of 2007, we can begin to understand how decision-support tools and information tailored to specific locations can improve community resiliency to storms.

A more sustainable Maine is one in which decisions today don't adversely affect the generations of tomorrow. Our findings could provide insight into current decision-making processes and how those processes might change to create more sustainable solutions for the future.

—Kim Ridley

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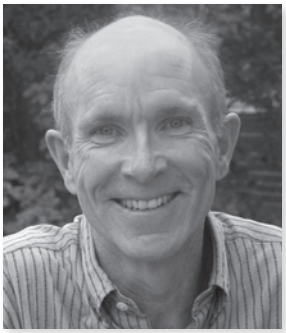

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