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Research for the Sustainable Development of Tidal Power in Maine

by Teresa Johnson

Gayle B. Zydlewski

Generating electricity from Maine's substantial tides has been a dream for generations. Today, as Teresa Johnson and Gayle Zydlewski describe, the state is poised for a new era in sustainable tidal-power development. A pilot project is already underway in the Cobscook Bay/Western Passage area near Eastport and Lubec. Tidal-power development presents technical, environmental, and social challenges, however, and the authors discuss how the Maine Tidal Power Initiative is working to develop a cooperative framework that integrates stakeholders, developers, and policymakers to tackle some of these challenges.

INTRODUCTION

Sustainable energy futures will require a diversified portfolio of alternatives (Bosetti et al. 2009; IEA 2010) that are carbon-free and environmentally acceptable. The energy crisis of 2008 brought to the forefront Maine's dependence on natural gas and other fossil fuels for home heating and transportation and pointed to the need to reduce this dependence to protect the economic well-being of the state. Currently, Maine's electric generation capacity is dependent (~60%) on natural gas, oil, and coal, none of which is indigenous to the state (OETF 2009). With the need to make serious choices about its energy future, the state of Maine considered its renewable portfolio standards in 2009 and decided to include a focus on the potential for ocean energy resources. The state enacted legislation to aggressively pursue a multifaceted strategy to diversify its energy portfolio with a variety of indigenous resources, committing to prepare for offshore wind, tidal, and wave power. While the technology for offshore ocean wind energy remains decades away, tidal power is currently feasible at the small-scale level, and commercial technologies are developing rapidly.

The need to sustain the Gulf of Maine's biological resources and existing marine uses while pursuing energy resources was a priority for the Governor's Ocean Energy Task Force (OETF). As such, one of the six subcommittees of the task force considered natural resources and human uses of the marine environment as potential challenges for ocean energy development and aimed to identify the best path forward to guide decision making about this new technology. Two of the largest challenges identified were the lack of knowledge about our ocean resources (baseline information) and the interaction of ocean energy development with other uses of the marine environment. The task force recognized the need to identify, manage, and resolve potential conflicts through early consultation and collaboration. A shared understanding of the proposed technology, how and where it would be deployed, and related cost considerations were recognized as critical components of the discussion.

Much uncertainty still exists concerning the risks and benefits of developing ocean energy (see the urgent call for research by Inger et al. 2009). Marine hydro-kinetic (MHK) energy captured from tides, also called tidal power, is carbon-free, but environmental impacts of MHK devices remain uncertain. Furthermore, power generation from the tides is restricted to areas of the globe that have tidal currents fast enough to generate power, e.g., peak currents of >2 m s^{-1} (or four knots) in areas with semidiurnal tides (Polagye et al. 2011). Areas in the United States with sufficient tidal energy include the Gulf of Maine, Puget Sound, and Cook Inlet, Alaska. Tidal-power developers have targeted these areas for innovative design and deployment.

Tidal-power development is new and presents a different suite of potential effects than does conventional river-based hydropower.

The major challenges and uncertainties related to tidal-power development include, but are not limited to, assessing environmental impacts, resource availability, technology efficiencies, community acceptance, and social-economic impacts. Tidal-power development involves complex interactions among biophysical and social systems, along with the intersection of the emerging technological components with the biophysical and social. Understanding the implications of these interactions is necessary for decision making and moving this technology forward in a responsible way. Regulators and developers must balance the uncertain consequences to marine resources and the environment in their decisions for advancing this industry. Tidal-power development is new and presents a different suite of potential effects than does conventional river-based hydropower. For this reason, federal and state agencies are taking a cautious approach, requiring rigorous environmental research and monitoring before approving permits. Entities proposing tidal-power development need assessments of potential environmental effects and impacts to obtain permits for pilot-scale deployments. They also need to monitor effects of pilot deployments to obtain licensing for commercial-scale deployments.

At the intersection of biological resources and community acceptance are fish communities and the

human communities that depend on them. Local communities are concerned about potential detrimental effects on their current uses of the marine environment, e.g., disruption of fishing activities or degradation of fish populations. Maine's marine resources are important to its people, culturally and economically. Maine's working waterfronts generate more than $740 million in income and support more than 26,000 jobs (Sheehan and Cowperthwaite 2004).

In this article, we present our integrated, stakeholder-driven research approach aimed to promote the sustainable development of tidal power. To illustrate the effort being developed by the Maine Tidal Power Initiative and Maine's Sustainability Solutions Initiative (SSI), we focus here on the integration between the human dimensions and biological research.

...the Maine Tidal Power Initiative... is developing a cooperative tidal-energy-development framework that integrates stakeholders, developers, and policymakers....

MAINE TIDAL POWER INITIATIVE

In response to the growing demand for knowledge necessary to develop tidal energy, an interdisciplinary team of engineers, biologists, oceanographers, and social scientists from the University of Maine and the Maine Maritime Academy are collaborating with tidal-power developers and state and federal regulators to promote the responsible development of tidal/marine hydrokinetic (MHK) energy. Organized as the Maine Tidal Power Initiative (MTPI), this group is developing a cooperative tidal-energy-development framework that integrates stakeholders, developers, and policymakers in environmentally sensitive, multi-use coastal communities. Although our work is focused primarily on the efforts in eastern Maine, we are also working with several smaller sites that are in earlier stages of development.

Vital to the MTPI framework is the importance of tailoring to the local social and ecological conditions of each renewable energy site and how energy resource development may be guided by principles that ensure broad, sustainable benefits to all citizens. These principles must be rooted in a solid understanding of the natural environment, state-of-the-art and well-suited technologies, sound economic returns, and broad social acceptance. Although the work of the MTPI will be transferrable throughout Maine and the U.S., our site-specific work is focused currently on Cobscook Bay/Western Passage near Eastport and Lubec, Maine, possibly the most viable commercial tidal energy site in the U.S. The team is investigating the potential for additional MHK deployment locations in Maine.

Taking SSI's sustainability science approach, which recognizes that responsible tidal-energy development, requires developing linkages and capturing feedback between social, engineering, and biophysical systems, MTPI brings together multiple disciplines and integrated research components. MTPI's seafloor geomechanics team is researching solutions and options for efficient and robust foundations for both fixed-bottom and floating tidal-energy devices. Using local information about sediment types, they are considering the complex lateral loading from currents and scour and sediment transport around foundations using experimental modeling.

The resource assessment team is researching the commonality and uniqueness of targeted MHK developments worldwide. Water current data collected at specific sites are used with modeling methods to assess MHK tidal resources, documenting the accuracy and uncertainties associated with different methods, and assessing the impacts of energy extraction on hydrodynamics.

The turbine engineering team focuses on characterizing baseline MHK systems to provide industry benchmarks to evaluate and compare emerging turbine technology with regard to energy-extraction performance. This focus includes the laboratory design and testing of standard turbine types and the development of experimentally validated design codes to assist the design of new turbines.

The fish assessment study team uses innovative field methods to determine the effects of MHK devices on fish, particularly their behavior and water column distribution. Multiple gear types and approaches are deployed at potential tidal project and control sites to develop models and protocols that allow industry, management agencies, and stakeholders to make informed decisions.

With funding from SSI, the human dimensions research team is engaging local groups and individuals to investigate factors that influence public support. By doing this they are identifying effective and efficient engagement practices that allow stakeholders to shape the direction of research on MHK device development and make informed decisions about MHK development in their communities and beyond, while at the same time improving the use of research in future energy policy making.

IDENTIFICATION OF INDUSTRY AND REGULATORY NEEDS

The fish assessment study team of MTPI has been stakeholder driven from the beginning. While formulating plans for tidal-device development and deployment in Eastport, the Ocean Renewable Power Company (ORPC) identified the need to consider the potential impacts of their activities on fishes, from both a technical and permitting perspective. Mechanical engineering colleagues at the University of Maine pointed ORPC in the direction of the School of Marine Sciences where there existed interest and expertise to help. With funding from the U.S. Department of Energy, within the newly formed MTPI, the fish assessment study team began identifying approaches to address the highest priority questions concerning fish interactions and responses to proposed ORPC devices.

Although ORPC started discussing permitting requirements with the Federal Energy Regulatory Commission, they had not yet started discussions with state natural resource regulatory staff charged with making decisions regarding deployment. Recognizing the difference between conventional hydropower devices and the open design of ORPC, the fish assessment study team designed a scientific approach (within budgetary constraints) to understand these basic questions:

- How do fish interact with an open design tidal device?
- Where and when are fish in the water column (particularly at the deployment depth of the device)?
- How does the tidal device affect fish distribution in the water column?

Methods included using sound to document fish distribution in the water column at all tidal stages, over multiple seasons at two sites (the planned deployment site and a control site), before and after a device would be deployed. The objective was to document the spatial and temporal changes in fish distribution in the region of a deployment of atidal device.

University of Maine scientists attended multiple meetings among ORPC and state and federal regulatory agencies (Department of Marine Resources, Department of Environmental Protection, Department of Conservation, Department of Inland Fisheries and Wildlife, U.S. Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration). The MTPI fish assessment study team's approach to assessing tidal devices was discussed and adjusted to address the questions of the regulatory agencies. For example, all agencies agreed that low fish abundance in the winter months could not be assumed and that information on fish presence and distribution would need to be collected year round. The team worked with ORPC to identify and secure funding to conduct sampling during all seasons rather than only the seasons that were expected to have high abundance of fishes.

In these meetings, regulators raised concerns about larger scale impacts. While the planned research would provide site-specific information about fish distribution in two locations, there was a question about fish presence and distribution in areas that were in the bay but not near the turbine (we call these "far-field" effects). Since little is known about fishes of Cobscook Bay, we needed to understand fish communities of the bay before one (or an array of) tidal devices would be deployed. Again, ORPC asked our fish assessment study team for an approach to this question and worked to secure funds to address the questions of bay-wide fish community impacts. Research began in spring 2011.

BOOTS ON THE GROUND: IDENTIFICATION OF COMMUNITY NEEDS

As stated earlier, there is a complex interplay of the biological (fish) community and local human community needs. Therefore, we initiated a study to understand the Eastport and Lubec community perceptions about the state of tidal-power development in the region. To facilitate this, we partnered with the Cobscook Bay Resource Center and the University of Maine Sea Grant and Cooperative Extension to identify stakeholder concerns and experiences related to tidal-energy development in eastern Maine. We were concerned with the community's broad perceptions and experiences related to tidal power. Not surprisingly, we were also interested to understand the work of the ORPC because it is currently the tidal project that is furthest along in this region and the Ocean Energy Task Force identified it as a community-based engagement model.

With our research partners, we set out to interview individuals in the community to ensure our research was informed by a diversity of stakeholder perspectives. We interviewed a total of 38 individuals representing a wide range of stakeholders from the communities around the Cobscook Bay. The majority of the stakeholder interviews were not recorded, but detailed notes were taken and then analyzed to better understand perceptions and attitudes about on-going stakeholder engagement efforts in the community, perceptions of potential positive and negative impacts, questions or concerns about tidal-power research, and familiarity with MTPI researchers and their research.

Community members were interested to learn more about tidal-power development; the majority of respondents interviewed (71 percent) stated that there were some aspects of tidal power that they would like to know more about. When asked what they would like to know more about, most expressed having questions about environmental impacts (including impacts to fish and other fauna) and issues related to tidal-power technology (including questions about the specific models being tested in the area, those available globally, and the ability of these devices to produce power). Other questions centered on uncertainties about the potential energy and economic benefits that tidal power may provide. We found similar results when we asked stakeholders specifically what they thought researchers should be studying. Understanding environmental impacts topped the list of what researchers should be studying related to tidal power. More interestingly, however, was that 70 percent of respondents reported that they did not know what University of Maine researchers were studying related to tidal power. As one informant noted: "We know they are studying …we don't know what they are doing." This suggested to us an opportunity to do a better job communicating our research in the community.

Fortunately, stakeholders provided valuable recommendations for how to better share our findings with the community. Most people identified public meetings as an appropriate forum, including formal briefings to stakeholders and public officials. Other more informal communication strategies were also suggested, such as face-to-face meetings and community gatherings. Respondents also recommended we write short articles in the local and state newspapers, such as the *Quoddy Tides* and the *Bangor Daily News*, and provide information through a public website.

In addition to these suggestions for where to communicate our results, we received valuable suggestions about how we should communicate (i.e., style). Most recommended that we be sure to communicate the results to a broader, nonscientific audience; for example, one individual expressed the importance of communicating publically funded research in a way that the public can understand: "Publically funded research needs to be passed to the public in such as way that their eyes don't glaze over." Similarly, another respondent explained:

> *maybe seeing those reports or a non-techno version of those reports in layman's terms to explain what they are doing and how they are doing it, and what they are collecting, and what they are finding out, and even the questions they are asking and the answers they are finding.…*

Others emphasized the need to disseminate the information broadly and informally to the local community:

Boots on the ground is the best way. People associated with the project talking directly to people.…The information can't just be given to a select few because they may not spread the word.…Just talk directly with people like at coffee shops and bars. That's how information is delivered locally.

It is interesting to note that many of the suggestions we received are not unlike the way stakeholders describe the approach that ORPC used in getting the word out about their project. One respondent suggested we might follow a similar approach:

The way it's been done so far by ORPC is a collaborative effort and that is good. You have to talk to local people on their level. Local people need to be made comfortable.

We intend to make use of these and other valuable suggestions as we move forward with our research in hopes of achieving the broad goal of improving the linkages between knowledge and action. For example, we have already developed a website for sharing our work with the public (http://umaine.edu/mtpi/overview/).

FINDING FISH: RESPONDING TO COMMUNITY CONCERNS

Armed with the knowledge of what community members wanted to know and how they wanted to receive information, we decided to tailor our research on the impacts to the bay-wide fish community (requested by the local regulatory agencies) to involve community members, particularly fishermen, more directly. Because we want to better understand the fish community in Cobscook Bay, a logical start to the study was to use local knowledge. We discussed our knowledge gap and needs with local fishermen and identified a place-based approach to achieving our goal of engaging with the fishing community in a two-way exchange of information about the fishes of Cobscook Bay. Our plan was to gather their knowledge to determine sampling locations and they would receive information from us regarding the fish in their backyard. Following recommendations from our community interviews, we organized a local meeting, sending invitations with hand-written notes to key individuals and advertising the meeting in the local paper, the *Quoddy Tides*, as had been suggested to us. A total of 13 people attended our meeting and provided suggestions and details on sites to sample. To facilitate two-way communication, we spent most of the meeting working in small groups, discussing the kinds of fish we would likely find in different parts of the bay and how we would or would not likely find them depending on when and how we sampled. The conversations were invaluable; we were able to modify our research design to improve the success of our effort. Keeping with the stakeholder-engagement model, we plan to return to the community in the winter to present the findings from our first year of sampling and solicit additional feedback about our approach as we move forward.

Better information conveyed to the general public, especially to local community members, is key to allowing productive dialogue and decision making about the risks and benefits of tidal power.

Following SSI's approach, we are working with federal and state regulatory agencies, tidal-power developers, and community stakeholders to better link our research to their needs. By engaging the users of the information we are being asked to provide, we are improving the chances that our research results will be more relevant to the decision-making processes that our stakeholders face, whether the stakeholder are developers interested to know if they should bother to develop in a location or regulators who need to make decisions about these projects on behalf of the public. Better information conveyed to the general public, especially to local community members, is key to allowing productive dialogue and decision making about the risks and benefits of tidal power.

Please turn the page for references and information about the authors.

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Teresa Johnson is an assistant professor in the School of Marine Sciences at the University of Maine. Her research focuses on marine fisheries management, social and ecological change in fishing communities, and stakeholder-driven collaborative research. She leads the human dimensions research team on tidal power development in the Maine Sustainability Solutions Initiative and the Maine Tidal Power Initiative.

Gayle B. Zydlewski is a research associate professor of marine sciences at the University of Maine. She studies migratory and marine fish and fish communities of Maine. Her current research focuses on how human-induced changes, such as river restoration and tidal power development, affect individual fish, fish populations, and the structure of fish communities.

Top 10 Ways SSI Is Using Tools to Work across Disciplinary Boundaries

Models: Using coupled social-ecological-economic simulations to understand, predict, protect, and enhance Maine's unique heritage, such as

- Social network analysis
- Bayesian belief networks and future scenarios
- Agent-based modeling
- Species-niche modeling
- Mediated modeling and participatory mapping
- Water-flow models

Social science methods: Using mixed-methods (quantitative and qualitative) to understand, predict, protect, and enhance Maine's heritage, such as

- Participant observations
- Targeted focus groups
- Interviews (structured, semi-structured)
- Surveys

Citizen science: Expanding and educating for improved science outcomes

Economics-based experimental games

Paleo-reconstruction to better understand historic landscapes and disturbance regimes

Maps for improved and long-term decision making.

Enzyme, isotope, and dissolve organic matter analyses to understand landscape effects on water

Molecular population genetics analysis

High tech tools, e.g., innovative radar tags for tracking movements of amphibians or other small-bodied organisms and automated loggers for water level

Low-tech tools, e.g., "One Orange," a stop watch and tape measure for stream flow.

"Top 10" lists provide a synthesis of common themes, methods, strategies and outcomes within SSI and reflect the collective input of more than 30 SSI faculty and students.