CONCEPTUAL MONITORING FRAMEWORK
FOR THE
PENOBSCOT RIVER RESTORATION PROJECT

Prepared by the Penobscot River Science Steering Committee
Edited by J. Royte, C. Schmitt, and K. Wilson
2008

The Penobscot River Science Steering Committee was formed in 2005 to help organize and coordinate scientific research and monitoring related to the Penobscot River Restoration Project (as recommended by the 2004 Penobscot River Science Forum). Today, the committee's mission is to guide and facilitate ecosystem monitoring and research opportunities related to barrier removal in the Penobscot River watershed, estuary, and bay by (1) providing guidance on priority scientific issues for the Penobscot River Restoration Trust, state and federal agencies, and other organizations; (2) exchanging information and sharing data from Penobscot River research and monitoring, and (3) identifying opportunities for collaborative research and education related to ecological restoration. The committee is coordinated by the Senator George J. Mitchell Center for Environmental and Watershed Research at the University of Maine.

Members of this ad hoc advisory committee, who volunteer their expertise, represent the following organizations and interests:

American Rivers
Bates College
Bigelow Laboratory for Ocean Sciences
Boston College
Boreal Songbird Initiative
BSA Environmental Consulting
Eastern Brook Trout Joint Venture
Lower Penobscot River Watershed Coalition
Maine Atlantic Salmon Commission
ME Coop. Fish and Wildlife Research Unit
ME Dept. of Environmental Protection
ME Dept. of Inland Fisheries & Wildlife
ME Department of Marine Resources
Maine Sea Grant
Penobscot Indian Nation
Penobscot River Restoration Trust
Senator George J. Mitchell Center
The Nature Conservancy, Maine Chapter
The Nature Conservancy, Eastern Region
Freshwater Program
Trout Unlimited
University of Maine
University of Southern Maine
U.S. Army Corps of Engineers

Monitoring the Penobscot River restoration, and its effects on riparian, estuarine, and coastal habitat demands extraordinary effort by many scientists from numerous disciplines, including ecology, biology, zoology, chemistry, hydrology, marine science, and socioeconomics.

This framework is intended to aid coordination and collaboration among the various disciplines involved, and serve as a resource for scientist and non-scientists interested in tracking restoration progress now and in the future. This document attempts to highlight opportunities for collaboration on research, field studies, funding opportunities, and data documentation and sharing. On the ground, effective coordination requires continual outreach to scientists working on the river, connecting people and data with restoration projects, and communicating lessons learned to the citizens, policymakers, and scientists concerned with river restoration and monitoring around the world.

Currently, Penobscot River restoration science is coordinated with a part-time position. The coordinator has three critical tools for coordinating activities: 1) the monitoring framework which provides the structure for related river monitoring and research activities; 2) the expertise and extended network of the Science Steering Committee listed above; and 3) the online portal to store and share information about science as the restoration progresses, including the scientists involved, near real-time results, access to data, and news:

http://www.pearl.maine.edu/windows/penobscot/index.htm

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I. PROJECT BACKGROUND

In June 2004, Pennsylvania Power and Light Maine, LLC (PPL), and federal, state, tribal, and conservation interests signed a final agreement to resolve outstanding fish passage, tribal, and other issues associated with the Federal Energy Regulatory Commission (FERC) relicensing of PPL's hydroelectric projects located in the lower reaches of the Penobscot River in central Maine, U.S.A. (Figures 1, 2). PPL agreed to sell three hydroelectric projects (Veazie, Great Works, and Howland dams) to the Penobscot River Restoration Trust (the Trust) for eventual removal or bypassing.[1] The Penobscot River Restoration Trust is a nonprofit organization legally charged with implementing the Lower Penobscot River Settlement Accord and is comprised of representatives from the Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, The Nature Conservancy, and Trout Unlimited.

The settlement agreement also provides for improved fish passage at four other PPL dams on the Penobscot River (Orono, Stillwater, Milford, and West Enfield). Successful implementation of the settlement agreement (referred to as Penobscot River Restoration Project, PRRP) is expected to result in the restoration of various ecological functions in the Penobscot River including connecting animal and plant species with their required habitat, and related effects on watershed food webs.

River restoration projects of the scope of the Penobscot are rare. The PRRP presents a significant opportunity to research and document the effects of ecological restoration, both for the Trust and for other communities considering dam removal or restoration activities. Removing two dams on a large river has not been attempted anywhere else in the U.S. to date. The most comparable project in the Northeast was the removal of the Edwards Dam on the Kennebec River in Augusta, Maine, in 1996. The Edwards Dam was the lowermost dam on a large Maine river, providing unimpeded access to an additional 17 miles of mainstem habitat. The results of that removal offer important guidance to the Penobscot project. The PRRP is a more ambitious project on a larger river: two dam removals, natural channel bypass construction at a third dam, and simultaneous fish passage improvement at remaining dams. In practical terms, *what can we learn from this project that will help us anticipate and minimize short-term negative effects, and maximize long-term positive effects of river restoration activities?*

As with most restoration projects, the PRRP will likely involve a combination of active and passive restoration techniques, each with some level of uncertainty, and a well-designed monitoring plan is critical for documenting positive and negative effects. Because of the spatial and temporal scale of restoration projects, it is often necessary to re-evaluate restoration efforts at various intervals to make necessary adjustments if monitoring disproves one or more assumptions of the project (USGS 2005).

This conceptual framework presents an approach for monitoring the restoration of environmental resources in the Penobscot River. We anticipate that, together with its online "living" counterpart, this framework will provide an exemplary and growing body of information on large river restoration and ecosystem responses that helps connect people to each other and to revitalized watersheds.

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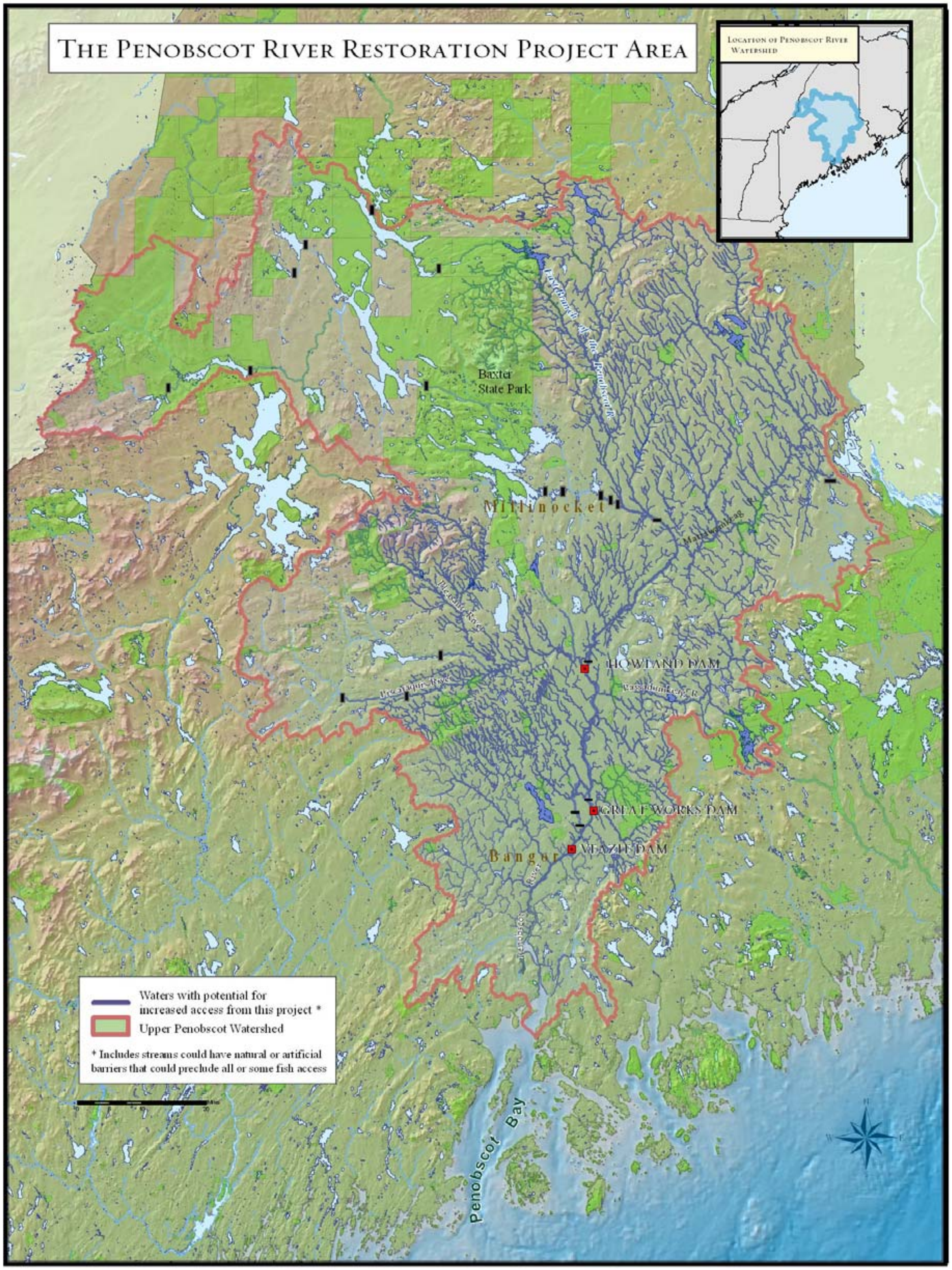
[1] The Howland Project may be decommissioned and have a natural fishway installed if found feasible.

Figure 1. Fish passage potential in the Penobscot River watershed.

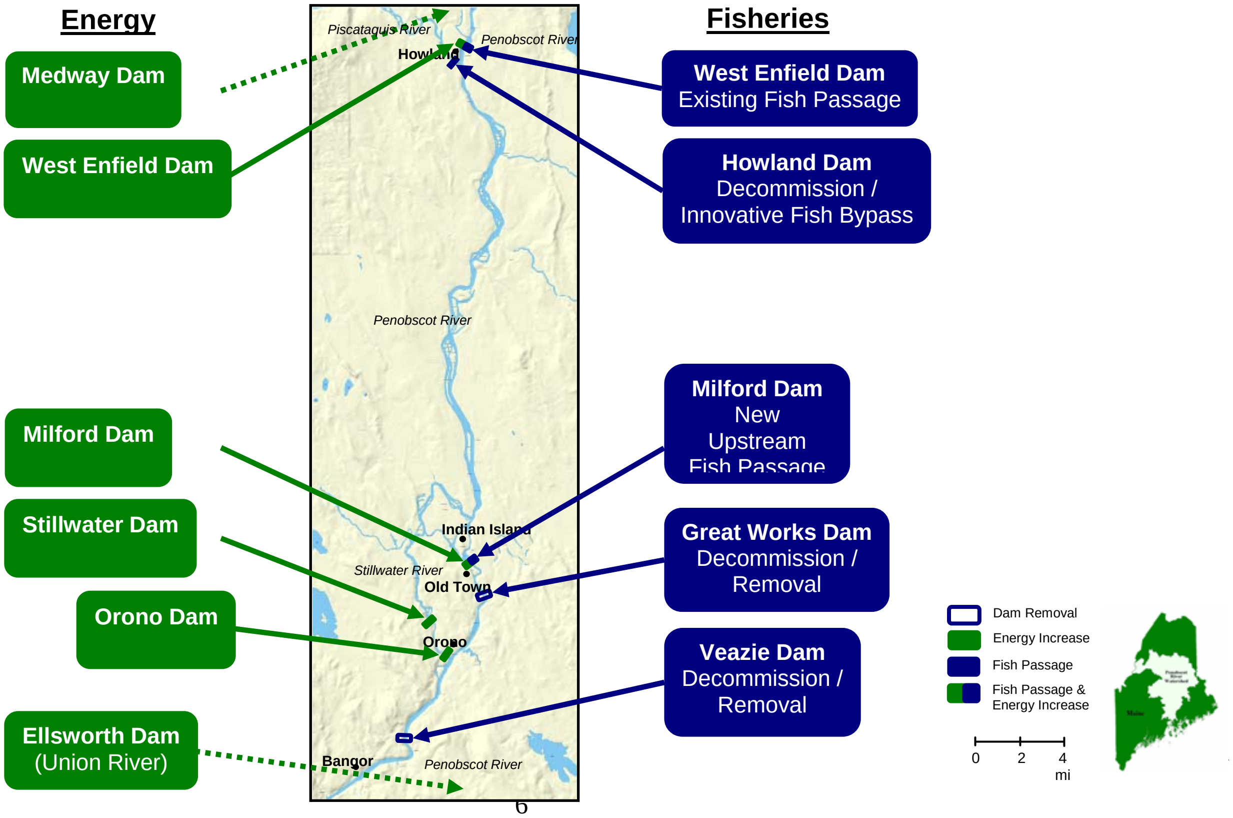


II. RESTORATION PROJECT GOALS AND OBJECTIVES

The broad goal of the Penobscot River Restoration Project is to restore populations of aquatic organisms, particularly diadromous fishes, and the related effects on aquatic, wetland, and riparian ecosystems upstream and downstream of the project focus area, including measurable effects in Penobscot Bay. The restoration is expected to positively affect wildlife, socioeconomic resources, and the Penobscot Indian Nation and other river communities. The Penobscot River Restoration Trust anticipates the following actions:

- Veazie and Great Works dam decommissioning and removal;
- Howland Dam decommission and construction of a natural fishway;
- Orono Dam recommissioned with a new upstream fish trapping facility and upstream American eel fishway(s) with continued operation of existing downstream passage facilities;
- Stillwater Dam outfitted with an upstream fishway(s) for American eels and new downstream passage facilities;
- Milford Dam receives state-of-the-art upstream fishlift and upstream and downstream passage for American eels, to replace the existing Denil fishway;
- River-wide, the project will facilitate interdisciplinary monitoring programs that will (1) generate data before and during removals that will allow for mid-course corrections to the project; (2) provide scientifically sound before-during-after comparison of the effects of dam removal and fish passage improvements and (3) provide context and basic environmental information for additional scientific study.

Figure 2. Relative locations of hydroelectric dams in the Lower Penobscot River.



III. MONITORING FRAMEWORK GOALS AND OBJECTIVES

This framework outlines monitoring objectives deemed critical by the members of the Penobscot River Science Steering Committee ("the Committee"), the 2004 Penobscot River Science Forum Workshop, and the 2006 Gulf of Maine Council on the Marine Environment River Barrier Removal Monitoring Workshop (Collins *et al.* 2007). These objectives are organized into seven research areas. These objectives are presented in one document to emphasize the importance of the whole ecosystem and the need for collaboration and interdisciplinary exchange of data and information to create an understanding of changes in the Penobscot River ecosystem as a result of dam removal.

Core parameters[2]

In developing this framework, our goal was to identify a set of "core parameters" for monitoring to ensure a scientifically sound assessment of change in the Penobscot River ecosystem in response to the PRRP. These core parameters are essential to cross-disciplinary research, and often are critical to multiple disciplinary questions. For example, basic water quality data are important for assessing changes in fish habitat as well as ensuring water quality attainment. **Core parameters that are particularly useful for multiple research areas are highlighted in bold throughout the text.** These are "cross-cutting" parameters that need only be shared by two research areas to be defined as such. A secondary goal of this document is to encourage networking among researchers, agency staff, and the Trust, so that the suggested monitoring and research studies will occur in collaboration. Most monitoring efforts have common data needs and/or can be conducted with shared human power and/or equipment. Concurrent monitoring (in time and space) of all aspects of the river system will greatly strengthen our ability to assess the effects of dam removal and fish passage improvements.

Monitoring study design

The proposed monitoring falls into one or more of four categories: monitoring required as part of project permitting (see Appendix A), monitoring to inform the restoration process, monitoring to document positive and negative effects of the project, and monitoring to expand scientific knowledge of large river ecology. Where possible, we have indicated which monitoring tasks will be accomplished, all or in part, through project permitting.

Restoration monitoring has been classified into at least three overlapping categories including implementation, effectiveness, and validation (Block *et al.* 2001; USFWS 2000; Federal Interagency Stream Restoration Working Group 1998). Implementation monitoring is used to assess whether or not a directed management action was carried out as designed. Effectiveness monitoring is used to determine whether the restoration action was effective in attaining the desired goals of the project. Validation monitoring is used to verify basic assumptions and scientific understanding concerning the restoration techniques and principles. This plan focuses on the types of monitoring particularly relevant to environmental resources affected by the PRRP: validation and effectiveness monitoring (hereafter referred to collectively as "restoration monitoring").

There are many potential study designs for monitoring single or multiple restoration actions (Roni *et al.* 2005). The Before-After (BA) study design is the recommended approach for many

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[2] Parameter is defined as a quantifiable characteristic or feature of the Penobscot. See also Collins *et al.* 2007.

applications involving stream restoration (Kocher and Harris 2005). The BA study design allows for knowledge of pre-treatment conditions and natural variability (Gerstein 2005; Minns *et al.* 1996). Good baseline data are required for valid BA study designs (Kondolf 1995; Minns *et al.* 1996). The main drawback of the BA design is that results can take years to manifest since it relies on the performance of the habitat restoration. BA study designs have been classified into several different types depending upon observation intensity (number of study sites, reaches, watersheds) and existence of controls (Roni *et al.* 2005). A common approach is the before-and-after control impact design (BACI) where a control site is evaluated over the same time period as the treatment site. The addition of a control site to a BA study design is meant to account for environmental (natural or otherwise) and temporal trends found in both the control and treatment sites (Roni *et al.* 2005). However, a BACI design with a poorly chosen control site can be less powerful than an uncontrolled before-and-after study design (Roni *et al.* 2005).

Choosing control sites for the PRRP is not straightforward, because although the project involves the lowermost reaches of the Penobscot River, the project is anticipated to affect some environmental resources throughout the entire 8,592-square-mile watershed. Comparable rivers that might serve as a control site or reference site do not exist, suggesting that a straightforward BA study design may be most appropriate for evaluating the PRRP. However, there is good reason to expect considerable environmental variability in the upcoming decades, suggesting that, for at least some aspects of the project, control or reference sites may be critical. For some monitoring tasks, sub-watersheds of the Penobscot may be suitable reference systems (e.g., Piscataquis River and East Branch). In addition, it may be possible to compare small upstream tributaries that could see an increase in diadromous fish access to other tributaries that will not see increased passage as a result of existing barriers.

We will not make specific recommendations here, because decisions regarding study design should be based on analytical power and may differ depending on the monitoring task. Detailed methodologies for barrier removal monitoring in streams are available in Collins *et al.* 2007, although these techniques may have to be adjusted or "scaled up" for use on the Penobscot River. We expect that the Science Steering Committee may coordinate final design decisions.

Temporal extent of monitoring

The effects of dam removal activities on some biotic and abiotic resources in the Penobscot River could take decades to be fully manifested in the ecosystem. Natural variations in fish and wildlife populations, life cycle periods, riparian recolonization, and many other factors will affect the ecosystem response to dam removal as well as our ability to detect a response. Recognizing the levels of funding and staffing needed to perform habitat restoration monitoring studies at a watershed scale, this plan attempts to present an attainable timetable and scale for pre- and post-treatment monitoring. In most cases we have assumed three potential years of pre-data before dam removal, although actual times may vary, and dam removals and passage improvements may be staggered over several years depending upon funding. For most core variables, data would be collected in years 3 and 1 before removal, and 1, 3, and 5 after removal. Additional sampling beyond the five-year time frame will be required for long-lived organisms such as fish and freshwater mussels. *In most cases, considerable information may be gained by measuring core parameters at or within the same time frame.*

Spatial extent of monitoring

Changes on the Penobscot are predicted to occur both in the immediate vicinity of dam removal (draining of impoundments, sediment movement and redistribution, changes in habitat for resident and migratory organisms, etc.) as well as throughout the Penobscot River watershed (distribution of resident and migratory/spawning diadromous fishes, potential spread of invasive species). To best take advantage of limited resources, the core parameters for each research area should overlap spatially as much as possible. For example, the same river cross-section or bay site could be used for morphology studies, tracking sediment movement, inventory sites for benthic invertebrates and aquatic plants, and transects could extend to the uplands to include wetland and riparian vegetation.

Recognizing the value of this approach, the Gulf of Maine Council has adopted cross-sections as the “backbone” of their stream barrier removal monitoring protocol (Collins *et al.* 2007). A detailed morphological survey (potentially developed as part of project permitting) should be used to guide selection of cross-section locations, but additional suggested criteria for locating transects include areas of expected change, such as impoundments, tributary mouths, and above and below the dam sites; upstream and downstream areas where indirect changes in food web structure may occur; and locations where minimal effects are expected, such as upstream from dams or other barriers that will not be removed. Because change may occur where it is not expected, monitoring should also occur at representative reach “types,” bay and estuary habitats, and at important infrastructure.

Hydrologic and benthic surveys completed as part of project permitting may provide the baseline for establishing cross-section locations. The Penobscot River Science Steering Committee has an informal transect subcommittee to propose these focal sites for sampling. Maps and related information will be posted to the Web site and amended to this document when available.

IV. DATA SHARING

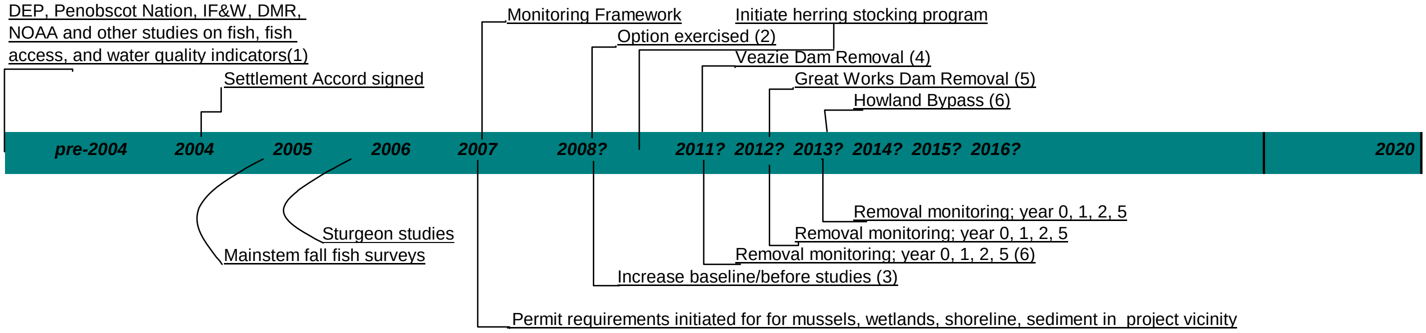
Data can be shared and made publicly available on PEARL (or a future reincarnation), the source for environmental information in Maine. PEARL, administered by the Mitchell Center, is already serving as the data and information sharing platform for the Committee and will continue to do so, contingent on future funding (http://www.pearl.maine.edu/windows/penobscot/index.htm). Also accessible via PEARL are links to existing online data sources. These links are structured in a spatially-referenced framework, allowing information searches by watershed, town, or waterbody for data on PEARL as well as other data sources. *A portal specific to Penobscot data needs to be created, as well as support for a data manager.* A mapping interface is currently under development by the Mitchell Center in partnership with College of the Atlantic. This interface will enhance access to Penobscot River research and data, but more support is needed.

V. FUNDING

A preliminary *annual* cost estimate for conducting the monitoring studies outlined in this document, including sampling, data analysis, and reporting, is $1,740,000. There is considerable overlap between these efforts and we anticipate that, with appropriate coordination, total costs could be reduced considerably. In some cases funding already exists for this work or potential sources have been identified.

VI. TIMELINE

The Penobscot River Comprehensive Settlement Accord filed with FERC in June 2004 established the timeline for implementing the PRRP. In accordance with the Settlement Accord, the five-year option period to purchase the Veazie, Great Works, and Howland dams expires in June 2009. At this time, the anticipate timeline is as follows:



1) Numerous agencies, organizations, academics, the Penobscot Nation, and other volunteers have monitored the Penobscot River, its fisheries, water quality, and wildlife for decades. For descriptions of studies and monitoring results see the Penbobscot River page on the PEARL: http://www.pearl.maine.edu/windows/penobscot/index.htm

2) Exercizing the option will depend on acquiring funds to purchase the dams; the timing of this occuring is not known at this time.

3) Monitoring to initiate before removal includes spring mainstem fish surveys (IBI), existing up and downstream passage, aquatic invertebrates up and downstream, including

4) While the timing of dam removal is unknown at this time, we hope that operations of dams for acquisition or removal costs won't exceed a few years.

5) It is also uknown whether it makes sense to remove a downstream dam before an upstream, if a year between is enough to mobilize deconstruction of the second dam or if there are economies of scale to doing the removals nearly simultaneously.

6) During and post-removal monitoring

VII. CONCEPTUAL MONITORING FRAMEWORK

A. Hydrodynamics, geomorphology and sediment transport

Barnhardt, W., A. Casper, R. Dudley, A. Kelley, T. Huntington, N. Snyder, and J. Reardon

Core parameters

Detailed river morphology/ bathymetric surveys, sediment chemistry (organic/inorganic contaminants), morphological cross sections**,** velocity surveys, and discharge measurements.

Background

Limited work in the Penobscot River (Dudley and Giffen 2001; J. Kelley and Barnhardt, pers. comm.) noted the abundance of coarse-grained sediment in the channel near Old Town, and limited exposures of fine-grained sediment associated with island margins. This observation may be related to the fact that the river developed in response to a steeper than present gradient under higher velocity and flow conditions. However, extensive archaeological work in the Bangor to Old Town reach shows thick (1-2+ m), fine-grained sedimentary sequences associated with tributary mouths upstream from local bedrock-cored base levels in the mainstem of the river. These deposits are the result of hydraulic[3] damming and slackwater deposition during high flow events. Stratigraphic and archaeological analyses of these sediments show that they have been accumulating since the Early Holocene, and continue to receive sediment during floods. Cultural resource investigations on the Piscataquis River related to the relicensing of the Howland Dam revealed the presence of similar deposits at the mouth of the Sebois Stream, as well as thick deposits of sand and finer material along the margins of several islands (Mack *et al.* 1997; Newsome and Sanger 1998). It is plausible to believe that similar deposits exist in comparable, untested settings in other portions of the Penobscot drainage.

Following European occupation of the region, an extensive network of dams was built on the Penobscot and major tributaries for log driving and hydroelectric power generation. Milford Dam is the site of the first major dam constructed on the mainstem river during the 1820s; the Great Works dam followed in 1830 (Cutting 1959). The Veazie Dam was built in 1886 as a pulp mill operation and was converted to a hydroelectric facility in 1891. These dams created higher, artificial base levels that raised water levels and drowned pre-existing rapids (Kelley 2006). The raised water levels have created fluvial and ice erosion of sedimentary sequences previously above annual floods (Kelley 2006). In addition, it is surmised that deposition of fine-grained material is currently taking place farther upstream in the surrounding tributary valleys. It is anticipated that this material will be mobilized at a lower base level. Lowered water levels may also impact older Holocene fine-grained deposits by under cutting and slumping, particularly during the spring freshet. All of these situations have the potential for moving fine-grained sediment into the river in response to dam removal. It is expected that these types of impacts will occur on less than six miles currently impounded by the two dams.

Dam removal projects in general reorganize sediment transport and channel morphology in the affected river system. Sediment previously trapped in impoundments and adjacent tributary mouths is made available for transport because of the lowered river base level. In the Penobscot

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[3] *Hydraulic* refers to water in motion, and describes that which is operated, moved, or affected by moving water, as with sediment carried by a stream. *Hydrologic* is a broader term that describes the properties, distribution, and circulation of water at varying spatial scales.

system, only Meadow Brook, a tributary to the Veazie impoundment, may be affected in this way. Banks that have been modified by impoundments are also susceptible to erosion. Deep water habitats that may have existed in impoundments are modified. Increases in sediment delivery to downstream areas can alter substrate conditions. For these reasons, a key component of a research and monitoring scheme for dam removals should include detailed bathymetric and sediment mapping and sampling (e.g., Dudley 1999; Snyder *et al.* 2006 and references therein on the Yuba River). The PRRP dams are "run-of-the-river" hydropower facilities located downstream of other mainstem dams, which likely limits significant post-dam sediment impoundment to localized areas in the mainstem and tributary mouths, which should be identified through detailed mapping. In addition, the Trust will make all attempts to control the decommissioning so that there is not a large load of sediment and debris moving downstream, and permitting requirements will likely address this—see Appendix A (The Trust, pers. comm.). Existing mapping (i.e., by Trust contractors Hydroterra and Kleinschmidt) within the impoundments provides useful information for planning and permitting, but further research and monitoring will require repeatable, high-resolution surveys of morphology and sediment characteristics.

The hydraulic modeling as presented here (see table below) is a high priority, as the results will set the spatial extent for much of the remaining monitoring for parameters that are expected to change with changes in hydrology. While we recognize that some of this work will be accomplished through permitting (and that permitting-related information will be added to the "living" document on the Web when available), we have chosen here to present the best available scientific opinion on effective and efficient restoration monitoring.

Core parameter	**Associated questions(?)**	**Rationale/expectations**	**Methods**
River morphology (riparian topography and bathymetry, stored sediment).	What are the effects of changed hydraulics on impounded areas and downstream? Will erosion due to lowered base level affect adjacent archeological sites? What is the fate of materials transported downstream? Can we calibrate models for predicting evolution of stream morphology and aquatic habitat after dam removal, applicable to other restoration projects in Maine and elsewhere?	Potential morphologic changes include: erosion and revegetation of channel banks in impounded areas, deposition of sediments stored in impoundments and at tributary mouths, loss of deepwater habitats. These data will provide a baseline for monitoring post-restoration changes to aquatic and terrestrial habitats.	• High-resolution bathymetric survey of impoundments, main channel, and upper estuary using a multibeam sonar system. Shallow areas may require a jet ski with single-beam fathometer with closely spaced survey lines. • High-resolution LIDAR topographic survey of river banks and wetlands, covering main stem of the river and major tributaries. • Register both surveys using Differential Global Positioning Systems, combine bathymetric and elevation surveys into one surface (with 1-2 pixels) using mapping software. • Map substrate texture and thickness using modern geophysical techniques (sidescan sonar, seismic reflection). Verify mapping with sediment sampling on a regular grid with archived samples, coring and bottom photography/ video. Areas should be resurveyed one year after project completion, and then again 3-5 years later.
Sediment chemistry (contaminants)	What is the relationship of sediment and water quality?	Stored sediments have the potential to move contaminants downstream.	• Analyze sediment samples collected as part of morphological survey for trace metals, organic contaminants (PCBs, dioxin, etc.).
Morphological cross sections	Do individual flood events affect the post-removal channel morphologic evolution?	Changes in channel, bank and floodplain morphology, sediment texture, vegetation and habitat will result from the dam removal.	• Survey shallow areas with a total station. • Survey mainstem with a jet ski and single-beam fathometer. • Establish photography stations at each cross-section. • Resurvey every three months during and after the project period. These surveys would provide greater temporal resolution than is available with high-resolution mapping, allowing for monitoring of changes in tributaries.
Velocity surveys and discharge measurements	What are the effects on habitats from changing sediment transport regimes? Where will flow velocity, impoundment extent, flooding frequency and amount change? How are hydrology, sediment transport, channel morphology, and critical habitat linked?	Dam removal will change flow hydraulics and flood hydrology upstream, within, and downstream of impoundments. Changes in dam management also will have important effects on the river system. Some of these changes can be anticipated through development of numerical flow models.	• Acoustic Doppler Current Profiler (ADCP) surveys of water-column flow characteristics. • Discharge monitoring at gauging stations. • Bathymetric and sediment mapping (above). • Develop a **predictive, dynamic spatial model** of post dam removal hydrodynamics from Howland to Bucksport to identify areas in the river, tributaries, and adjacent riparian areas where changes in flow velocity, sediment transport, impoundment extent, and the frequency and amount of riparian inundation, are expected to occur with dam removal. This model should identify anticipated changes compared to present conditions, temporally (by season) and spatially. (Note that this model, at least in part, will likely be part of project permitting. See Appendix A.)

B. Water Quality

Courtemanch, D. and T. Huntington

Core parameters

Basic water chemistry, estuarine dissolved oxygen, water column nitrogen and phosphorus, time-of-[water]travel, PAR, dissolved oxygen time series, sediment chemistry, **water and sediment contaminant levels**.

Background

The Penobscot Nation conducts regular water quality monitoring including basic water chemistry and macroinvertebrate monitoring in the river and many of the significant tributaries in the area of the restoration. The DEP conducts river-wide monitoring on a rotating basis including basic water chemistry, macroinvertebrates, algae (tributaries), and fish tissue contaminant analysis.

Data from water quality studies conducted by the Maine DEP and Penobscot Indian Nation in the late 1990s on the Penobscot River below Mattaceunk and the Piscataquis River have been used to construct a preliminary water quality model for dissolved oxygen for the river (QUAL2EU; MDEP 2003). The segment of the river from the confluence with the Piscataquis to the head of tide attains all water quality criteria except for fish consumption (due to the presence of mercury, dioxins, and PCBs). The segment between Bangor and Bucksport does not always attain dissolved oxygen or bacteria criteria (presumed to be effects of wastewater discharges and combined sewer overflows). Because of non-attainment, the Penobscot Nation and Maine DEP are working with EPA to develop a total maximum daily load (TMDL) for the lower Penobscot. In recent years, significant algae growth has been observed throughout the river, originating from high nutrient loading conditions in the West Branch. The Penobscot River has recently, and continues, to go through a number of profound changes that affect water quality. These include changes in hydropower operations on both the West and East Branches; changes of ownership and production at paper making facilities on the West Branch; closure, reopening and expansion of Lincoln Pulp and Paper; closure of the Georgia Pacific plant (Old Town) and reopening as a pulp and biofuel facility; closure of Eastern Paper in Brewer; and upgrades in municipal treatment at Bangor and Brewer. In response, Maine DEP is revising the model to reflect current conditions based on sampling results from the summer of 2007.

From 1979 to 1994, the USGS maintained a gage and multi-parameter water monitoring station at Eddington. This gage was reactivated in 2007, and additional gages are maintained at Enfield on the mainstem, Medford and Dover-Foxcroft on the Piscataquis, and at Grindstone on the East Branch. The USGS began monitoring water temperature at Eddington on September 6, 2006). Additionally, a station on the West Branch near Medway provides daily discharge data.

Researchers at the University of Maine are investigating mercury in water and sediment south of Orrington related to releases from the former Holtrachem facility (Merritt 2006). A further, more comprehensive study of mercury in the estuary has been initiated as a result of a court settlement (D. Bodaly, pers. comm). There has also been limited study of sediment contamination in the vicinity of Dunnett's Cove in Bangor (Bangor Gas Works; Elskus 2006). GoMOOS buoy F (operated by the University of Maine) is located in Penobscot Bay near Rockland. The station monitors chlorophyll, solar radiation, ocean color, and particle scattering. Researchers are using these data to monitor particulate and dissolved matter entering the bay, accompanied by chemical analyses of samples collected around the watershed (C. Roesler, pers. comm.)

Core parameters	**Associated questions/objectives**	**Rationale/expectations**	**Methods**
Temperature, DO, salinity, conductivity, BOD_5, BOD_u, TSS, phosphorus, chlorophyll-*a*, trace metals, contaminants, **sediment chemistry.**	Collect required data for dam relicensing/surrender. Does the river achieve regulatory attainment of water quality? Are there changes in TSS load after dam removal?	Basic water quality parameters are required for regulatory purposes, as well as a contextual base for assessing spatial and temporal trends before and after restoration project.	• The Maine DEP and the Penobscot Indian Nation have ongoing sampling programs in the lower Penobscot River. • Secure funding to maintain water quality sampling at the USGS Eddington gage and GoMOOS buoy F. • Additional sampling dates and sites may be needed, especially further upriver and downstream in the estuary.
Dissolved oxygen in Penobscot Bay/River interface	Does the estuary achieve water quality attainment?	Characterize relative inputs of DO to the estuary.	• Grab samples and/or data loggers (perhaps as a cross-cutting parameter in coordination with hydroacoustic array).
Water column nitrogen and phosphorus (by nutrient species)	Are there changes in flux & origin of nutrients in the river?	Incoming (or outgoing) diadromous fish will add (or remove) nutrients.	• Water column nutrients should be measured in conjunction with diadromous fish runs marine-derived nutrient study (stable isotopes).
Time-of-[water]travel	Recalibrate DEP river model QUAL2EU.	Recalibration and analysis of the model may result in revised wastewater licenses.	• Construct/calibrate final river model (QUAL2EU) for use in wasteload modeling to establish new interim wastewater licenses for each mill on the river (2007-08).
PAR, dissolved oxygen time series, **stream morphology** [see section A] and **hydrologic data** [see section A].	How do primary productivity and metabolism change?	Increases in dissolved oxygen, coupled with changes in morphology and hydraulics, may increase or decrease metabolism.	• Collect time series of dissolved oxygen and temperature and a time series of PAR. • Construct and calibrate Whole Stream Metabolism program (WSMP) for use in assessing gross primary productivity, net metabolism, and daily respiration.

Water Quality abbreviations:
BOD – biological oxygen demand
TSS – total suspended sediments
PAR – Photosynthetically Active Radiation

C. Wetland and riparian plant communities

Calhoun, A. and C. Loftin

Core parameters

Changes in the extent (size), distribution, and vegetation composition (species types and dominance including invasive species dominance) of aquatic and riparian plant communities.

Background

Submersed and emergent wetlands associated with the impoundments and nearby tributaries may be affected by potential changes in water levels, flow rate, and sediment dynamics that result from the dam removals. These natural communities may experience changes in water quality from the increased oxygen and nutrient dynamics due to both dam removal and subsequent changes in fish abundance. Other dam removal and fish access case studies suggest that there will be an influx of marine-derived nutrients that are quickly absorbed into in-stream and potentially nearshore habitats through the food web and direct deposition (e.g., Walters and Post 2007). Plants also play a role in stabilizing newly formed banks.

Several sites along the mainstem Penobscot and many of its tributaries harbor rare plants such as Steinmetz's bulrush and exemplary natural communities such as silver maple floodplain forests. It is not clear what effects the project would have on these habitats.

The drawdown zone and disturbed soil at the construction site and downstream may provide opportunities for invasion by non-native plant species. The Maine Natural Areas Program has not completed an aquatic plant survey either for rare species or invasive species along the Penobscot River, although several exotic/invasive wetland plant species, purple loosestrife (*Lythrum salicaria*), and common reed (*Phragmites australis*) are known to occur throughout the watershed and may be expected to colonize newly dewatered areas along the river as a result of the restoration project. Flowering rush (*Butomus umbellatus*) is known to occur in the Kenduskeag drainage but does not appear to be expanding its range at this time. At this time, there are no reported invasive aquatic plant species.

The Nature Conservancy and University of Maine have begun an assessment of existing wetland extent in the project area and wetlands within the 100 year floodplain and associated with tributaries. Recent student efforts to assess wetland extent and species composition of fringing marshes in the tidal portion of the lower river have found that some areas are misclassified or omitted on NWI maps (Kropp 2007, S. Yost, pers. comm.). Wetlands in the immediate project area of the impoundments are being assessed as part of project permitting.

The Department of Environmental Protection wetland biomonitoring program sampled the Penobscot Basin in 2006. Biological sampling includes aquatic macroinvertebrates, epiphytic algae, and phytoplankton. Water samples are analyzed for nutrients, chlorophyll-a, etc. DEP also collected data on algal communities from streams in the Penobscot Basin.

Core parameters	Associated questions	Rationale/expectations	Methods
Size, extent, and species composition of wetlands in the drawdown area and downstream	How do riparian habitats respond to drawdown? Do rare plants and exemplary natural community sites change in response to food web nutrient changes?	Drop in water level above dams may result in a loss of wetlands in some areas, while other areas will develop new riparian zones and wetlands. Floodplain communities if exposed to increased levels of marine-derived nutrients could see increased productivity of some species.	• One year prior to removal and one year after drawdown (to document initial response), map stream-associated wetlands in the entire area expected to be impacted by drawdown and potential sedimentation or erosion downstream. • Using bathymetry, hydraulic model, NWI maps and aerial photographs, as well as field verification, identify areas of the river and surrounding drainages where wetlands will potentially be affected by changes in sediment distribution, water depth, flow velocities, and hydroperiod. **Establish transects (co-located with morphometry and mussel cross-sections) to document wetland vegetation change pre- and post dam removal.** Transect data should include vegetation-dependent fauna (i.e., dependent on structure or species composition) and seed bank composition. One year prior, one and five years from dam removal, re-do transects to describe longer term trends. • Survey rare plant and natural communities with plots. If increased production noted then nutrient studies to track potential link to fish.
Invasive species	Do invasive plant species expand in range as a result of the dam removals?	Increased connectivity and newly exposed banks may provide an opportunity for invasive species to colonize new areas.	• Streamside surveys for invasive plant species in areas likely to experience habitat changes, especially newly exposed sediments.
Wetland function	Are wetland functions altered as a result of dam removal?	Changes in flora, fauna, and ecosystem processes may alter or enhance the function of riparian wetlands.	• Perform functional assessments on existing wetlands (flora, fauna, ecosystem processes) to provide comprehensive baseline pre-dam removal data and for post-dam removal comparison.

D. Aquatic Fauna 1. Fish communities

Trial, J., J. Murphy, *et al.*

Core parameters

Changes to: 1) total fish biomass and production, 2) temporal and spatial fish community structure (i.e., species richness, distribution of biomass, and production, including non-native fish expanding into new areas), and 3) biomass, production, and animal nutrient and toxicity content.

Background

Dam removal will affect the fish communities in the impoundment areas that will become free flowing, from habitat changes as well as increased access to more and additional species of diadromous fish. The addition of new and more abundant diadromous fish species could potentially affect the entire ecosystem through changes in competition for resources, additional nutrients, new nutrients, potential dilution of in-stream contaminants, and changes in fish prey and predator structure, as well as pest and pathogen access.

Introduced fish species may expand in range as barrier removal provides access to new areas of the watershed, and as a result of habitat modifications that allow colonization in areas previously unsuitable to introduced species. Of the 20 fish species identified in the mainstem, and 18 in the tributaries, upwards of half of all species at any site were introduced, and even greater percentages of total fish population at some sites were made up of introduced species, notably centrarchid species (Yoder 2004) while the majority are already widespread throughout the project area and would not be affected by the restoration project, at least two species, northern pike (*Esox lucius*) and central mudminnow (*Umbra limi*), are recent introductions only known to occur in a limited area and any removal of barriers could enhance their movement into new portions of the watershed.

Studies of fishes can occur at the individual, population, and community levels (Minns *et al.* 1996). Restoration monitoring in the Penobscot River based on indices at each of these levels of organization will address the range of ecosystem functions potentially affected by the PRRP. The Maine Bureau of Sea-Run Fisheries and Habitat along with other state and federal resource agencies released a final Strategic Plan for the Restoration of Diadromous Species to the Penobscot River in March 2008. The plan develops species-specific restoration goals for the Penobscot River based upon habitat, water quality, species life history, etc. To assess the results of the PRRP, a whole-life history model could be developed using data collected during monitoring studies. Estimates of age/size specific survival, growth, fecundity, etc. could be weighted by production goals to identify where bottlenecks exist in meeting restoration goals. Also, data collected during restoration monitoring studies could be used to periodically calibrate species-specific restoration goals of the management plan within a whole-life history model.

A recent review of historical populations of diadromous fish and how those populations may have interacted with salmon populations in the Penobscot, using board of agriculture and fisheries commissioner reports from the last 200 years, provides a baseline for pre-dam conditions and restoration potential (Saunders *et al.* 2006). In addition, historical fish passage information is contained in FERC and NEPA relicensing documents and applications. The Maine Atlantic Salmon Commission coordinates trap counts at Veazie and Weldon dams in addition to routine monitoring of juvenile salmon populations, available habitat, and redd counts. A current research project to assess sturgeon populations and habitat in the Penobscot provides before-dam removal information for both Atlantic and shortnose sturgeon (M. Kinnison, G. Zydlewski, S. Fernandes, University of Maine).

A team from the Maine Cooperative Fish & Wildlife Research Unit, University of Maine, and NOAA-NMFS tracks migration of stocked Penobscot River salmon smolts using ultrasonic telemetry to study movement patterns, mortality, and migration delays. NOAA also deploys rotary screw traps below the Veazie dam from April to November. Further out in the estuary, the National Marine Fisheries Service began a post-smolt trawl survey and smolt mark-recapture studies in 2001. Their array of hydroacoustic receiver buoys in Penobscot Bay could be utilized for tracking other species.

Core parameters	**Questions**	**Rationale/expectations**	**Methods**
Fish growth, abundance, biomass, production.	Have diadromous or resident fish populations changed with dam removal and passage improvements?	Dam removal and passage improvements will increase populations of diadromous fishes; resident fishes may be displaced by diadromous fishes.	• Continue using Index of Biotic Integrity (IBI) protocols already in use on the river (Yoder and Kulik 2003; Yoder 2005).
Fish movement, **species richness.**	Has the extent and rate of diadromous fish (and resident fish) movement changed in response to dam removal and passage improvements? Have survival rates increased with improvements in fish passage?	Dam removal and passage improvements should increase migration success (and speed?). Fewer dams and improved fish passage should improve survival rates.	• PIT tag and ultrasonic telemetry studies of fish movement. • Counts of all fish species at dam passage facilities. • Studies should focus on *extent* of movements, as well as the efficacy of fish passage before and after improvements. • Note that presently Atlantic salmon are the only diadromous fish to occur above the Veazie Dam in large enough numbers for pre-dam removal tracking.
Juvenile diadromous fish migration.	Do survival rates and passage rates of juvenile Atlantic salmon smolts and other diadromous fishes increase?	Removal of dams should reduce fatalities associated with downstream fish passage.	• Rotary screw traps deployed below site of Veazie dam from April to November, continuing work by NOAA NMFS Maine Field Station.
Returning diadromous fish counts.	Do returns of diadromous fish increase? Has freshwater residency time of diadromous fish changed in the river?	Dam removal and passage improvements should increase the returns of diadromous fish to the river.	• Continued counts at existing dam passage structure. Many of these counts must be conducted as part of FERC licensing agreements. Based on life-history constraints, returns may take some time to increase (i.e., years at sea before adults return)
Occurrence of “invading” fish species (pike, mudminnow).	Are invasive species spreading into new habitats?	Barrier removal may provide opportunity for colonization by invasive fish species.	• Monitor upstream and downstream of Milford and Howland through trap data at these two facilities.
Estuarine fish population parameters (abundance, distribution).	Do estuarine fish populations respond to increases in diadromous fish runs?	Increases in diadromous fish runs may be accompanied by increases in (1) juvenile and adult diadromous fishes in the estuaries and (2) increases in their predators.	• Hydroacoustic survey of Penobscot estuary for fish abundance (presence) and distribution. **Additional information on Penobscot estuary phytoplankton and zooplankton distributions and abundance could be collected at the same time.** Rotary screw traps could be used to calibrate hydroacoustics.

Aquatic Fauna 2. Benthic macroinvertebrates and freshwater mussels

Loftin, C. and B. Swartz

Core parameters

Benthic macroinvertebrate community structure, mussel distribution, relative abundance, microhabitat use, population age/size distributions, presence and condition of marked individuals, **fish host identification, distribution, and abundance,** mussel condition (glycogen levels) and **contaminant loads.**

Background

Benthic macroinvertebrates have been collected along the river on a regular basis by Maine DEP and the Penobscot Nation since the early 1980s, but not recently in the Veazie (1994) or Great Works (1999) impoundments. Most recent work has been focused on the West and East Branches with less intensive sampling on the mainstem.

The Maine Department of Inland Fisheries and Wildlife has identified sites in the Penobscot River and several tributaries between Howland and Bangor with two state-threatened freshwater mussel species (tidewater mucket, *Leptodea ochracea*; yellow lampmussel, *Lampsilis cariosa*), two species of special concern (creeper, *Strophitus undulatus*; triangle floater, *Alasmidonta undulata*) and one candidate for state-threatened status (brook floater, *Alasmidonta varicosa)*; Nedeau *et al.* 2000). Surveys conducted in the mid 1990s broadly mapped mussel distributions across the state; hence, the surveys were not comprehensive within a site. Although presence of these species was documented, there is no comprehensive information about mussel distributions, density or population estimations, or population age/size distributions of these species in this region of the river and its tributaries. Given that current distributions and abundances of freshwater mussels in the river are not well-known, effects of these dam removals on the freshwater mussel populations are not clear.

Most freshwater mussels depend on specific fish species to host and disperse their larvae. Fish communities in the river and tributaries are expected to change following dam removal, as increasing numbers and different species of fish move into previously inaccessible or unoccupied habitat. Although greater access to suitable host fish is likely with dam removal, displacement and redistribution of host fishes is also possible. Changes in nutrients may alter food availability for mussels, especially if high quality phytoplankton are displaced by a lower quality assemblage. It is difficult to anticipate changes in mussel populations that might occur, given the current lack of knowledge about the existing mussel community composition and distribution, fish host identification, habitat and food resource needs, and mussel tolerance to habitat change.

Removal of dams presents a situation for freshwater mussels that has been experienced in only a few locations in North America and never at this scale. Although dam removals are increasing throughout the country, few cases have affected listed mussel species. A recent study of mussel translocation methods and mussel distributions at another site where dam removal is pending, the Fort Halifax Dam impoundment on the Sebasticook River (Kurth 2007), will provide insight into determining the current and potential distributions of freshwater mussels and their fish hosts in the Penobscot River and tributaries, as well as provide information on the potential success of using mussel relocation as a tool to minimize effects of dam removal.

Core parameters	**Associated questions**	**Rationale/expectations**	**Methods**
Mussel distribution, relative abundance, microhabitat use (concentrating on species of conservation concern)	Where are rare species currently located in the river and tributaries? What microhabitats are currently used by mussels in the river and tributaries? What suitable but unoccupied habitat exists?	Improved mussel habitat may be created downstream from the project area, and there may be loss of habitat in the dewatered area, and/or no change in upstream areas. Mussels could be harmed by increased sediment.	• Qualitative snorkel and dive mussel surveys based on MDIFW surveys and available bathymetric maps. Surveys should cover areas expected to experience altered hydrology following dam removal, as well as control areas. • **Habitat surveys (including benthic environment and hydrological conditions) conducted over several years (June-September) prior to dam removal.** Surveys should note species identifications and relative abundances. Because mussels remain burrowed for most of their life cycle, repeated surveys over the same areas are necessary to account for seasonal dynamics in the above-ground portion of the population. Post-drawdown monitoring should continue annually for 5+ years. • Tissues from individuals sampled for identification purposes should be properly preserved for stable isotope and contaminant analyses.
Population age/size distributions	What are current mussel population sizes, densities and age structures? Is there evidence of population growth?	The presence of all age classes indicates that conditions are suitable for population persistence, which can be confirmed with monitoring over several years to document reproduction and survival of young age classes.	• Using qualitative information from above, surveys of density estimates and variances among plots and valve measurements, following methods outlined by Strayer and Smith (2003). Surveys repeated over several years before and after dam removal. Sieving to determine buried component of population. • Mark-recapture studies to determine proportion of population observed at any one time, population change over time, and survival of age classes.
Presence and condition of marked individuals.	What proportion of mussels are recaptured after dam removal, and what is their condition at recapture?	The fate of translocated mussels will be unknown without long term monitoring of marked individuals.	• Mark-recapture studies of individuals translocated to sites outside the project area and individuals retained within the project area, to determine proportion of population observed at any one time, population change over time, survival estimates of age classes, and physiological condition. Areas currently unoccupied also should be surveyed to determine if these areas are colonized after dam removal.
Fish host identification, distribution, and abundance	Which fish species are suitable hosts for mussels, and where are they found?	Freshwater mussels require a host fish to nurture and transport mussel larvae upon release from the brooding female mussel.	• Based on methods established by Kneeland (2007), identify fish host populations and evidence of infestation by mussel glochidia of species found in the qualitative and quantitative mussel surveys, concurrent with fish surveys in proximity to existing mussel beds during breeding season.
Mussel condition (glycogen levels) and **contaminant loads**	What is the physiological condition of mussels in the river and tributaries before and after dam removal?	Physiological stress may indicate declining condition. Tissue contaminants may reflect changes in river contaminants.	• Tissue samples collected from mussels tagged in mark-recapture studies; tissue can also be analyzed for stable isotope ratios to determine role of mussel in the river food web, and changes that occur with dam removal, as well as contaminants.
Benthic macroinvertebrates	How do invertebrate communities respond to changes in water quality?	Expect shift from lentic to lotic communities.	• Sampling to document benthic invertebrate communities should occur at Veazie, Great Works, Milford, Howland and Enfield impoundments, transects, and bay locations.

Aquatic Fauna 3. Avian life

Wells, J.

Core parameters

Avian species diversity, abundance, habitat use, reproductive success, behavior, changes in food sources, contaminant accumulation.

Background

Bird life in, over, on, and around the Penobscot is expected to respond to restoration activities including increases in new riparian zone vegetation, and changes in aquatic food availability associated with changes in fish species and populations and overall ecosystem productivity. Increased fish access is expected to boost numbers and diversity of potential prey species as well as enhance riverine and riparian ecosystems through increased nutrients (dead fish, spawn, and waste products). The addition of migratory fish may dilute in-stream contaminants that may currently impair birds and their dependent food web. For purposes of before-and-after monitoring of bird community response to watershed restoration, the various bird species that use the river and adjacent habitats can be partitioned into several ecological or indicator groups based on foraging ecology in relation especially to other animal and plant communities in or adjacent to the river. These indicator groups could include:

a. fish-eating species (common merganser, double-crested cormorant, great cormorant, great blue heron, green heron, osprey, bald eagle, various gulls, belted kingfisher);
b. aquatic invertebrate specialists feeders (bufflehead, common goldeneye, Barrow’s goldeneye, some gulls, various shorebird/sandpipers);
c. aerial insectivores (swallows, cedar waxwings, sometimes gulls);
d. terrestrial insectivores (various migrant and breeding landbirds);
e. aquatic herbivores (mallard, American black duck, green-winged teal) and;
f. marsh inhabiting species (rails, herons)

Ongoing monitoring by MDIFW of bald eagles includes nest location, eagle residency, and eaglet production, as well as historic and anecdotal locations of osprey nests. The agency also has historic data (1976-1981) on eagle food habits from prey debris collection at nests from over 150 sites in Maine. U.S. Fish and Wildlife Service has six years of monitoring data on organochlorines, dioxins, furans, and heavy metals in eagle eggs. The BioDiversity Research Institute has surveyed mercury residues in eaglet blood and feathers from sites in the Penobscot River; this work is continuing in the Penobscot estuary in 2007. Mercury in other bird species has been measured as part of an ongoing court-ordered evaluation of the lower Penobscot River (D. Bodaly, pers. comm.). These programs could be amended or expanded to document pre- and post-restoration mercury and other contaminant loads in a range of bird species from individuals that are known to nest and forage in and adjacent to the river (Evers and Clair 2005).

Core parameter	Objective question	Rationale/expectations	Methods
Species abundance and diversity and changes in use (timing, frequency eating, perching, etc.)	Do indicator species numbers and behavior change due to restoration activities? What is the spatial and temporal variation of bird species?	Increased numbers of birds could be expected to spend more time foraging in, on, and near the river, including new riparian zones, and have higher reproductive success due to both increased forage and forage nutrient quality. Changes in abundance or diversity may indicate changes in the ecosystem components.	Before, during, and after dam removal, document avian diversity and abundance on and adjacent to the river from below former Bangor Dam to above Howland dam throughout the year. Breeding bird, migration and winter bird counts during high activity times that will include nest surveys and spatially focused surveys in areas with new riparian vegetation, and in areas where increases in fish are expected. Timing (pre- and post dam removal): • One-two fields seasons of pre- removal monitoring to collect enough data to map communities and survey key transition zones. • Field season one year after drawdown (document initial response). • Five years from dam removal to help describe the longer term trends. • Ten years from dam removal when fish populations will have begun to respond to new habitat.
Marine-derived nitrogen	Are marine-derived nutrients supporting avian food sources?	Marine-derived nitrogen is expected to become more prevalent in birds as sea-run fish import more marine-derived nitrogen into riverine and associated ecosystems.	• Tissue or blood samples from birds (including their eggs) that spend a majority of their time on and around the river are sampled for marine derived nutrients using isotopic analysis to document foraging ecology and the trophic levels at which different bird species are using within the river ecosystem (Hobson *et al.* 1994, Paszkowski *et al.* 2004, Romanek *et al.* 2000)
Contaminants	Will contaminant loads decrease or increase with changes in hydrology and sediment loads?	With increased flow in impoundments and increased fish in and out, migration of contaminants in the system should decrease.	• Tissue and/or blood sampling for contaminants. Annual surveys documenting the numbers and location of nesting bald eagles, osprey, kingfisher, and perhaps great blue herons, and riparian breeders, are carried out within the watershed region likely to be impacted by the restoration activities. Ideally this would include (at least for some species) a measure of annual reproductive success.

Aquatic Fauna 4. Marine and freshwater mammals

Royte, J. and E. Summers

Core parameters

Abundance and composition of piscivorous mammals (seals, otter) utilizing the river, estuary, and the riparian zone in areas subject to increased fish access. **Contaminants** and **marine-derived nutrients** in mammalian predators.

Background

Increased fish access and associated food web enrichment, particularly upstream of dam locations but potentially downstream as well, is expected to attract mammalian predators such as grey seals and harbor seals, river otters, raccoon, and fisher. Seals have been observed beyond the former Edwards Dam site in the Kennebec River (Sherwood 2006). Maine Department of Inland Fisheries and Wildlife maintains harvest data on river otter, which are trapped in November and December. Statewide, 1,112 otters were harvested in Maine in 2005. Their overall population status is unknown. A study in the *Journal of Mammalogy* (Docktor *et al.* 1987) found that otters in Maine seem to have a stable reproductive rate, but mercury pollution may be a problem. Studies by the BioDiversity Research Institute have looked at mercury levels in otters near the mercury-polluted Holtrachem site in Orrington. Mercury levels in brains were below the concentrations that cause acute death, but levels in their fur were high, indicating chronic exposure (Yates *et al.* 2005).

In addition, more sea-run fish, which tend to be lower in contaminants than freshwater residents, may change the nutrient and toxics loads in predators and their offspring. Indirectly, mammals may have increased nutrient uptake of food web components such as aquatic vegetation (moose), aquatic insects (shrews, mink), and mussels (otter, mink, fisher).

Core parameters	**Associated questions**	**Rationale/expectations**	**Methods**
Aquatic and marine mammal use, timing, abundance and diversity	Do indicator species numbers and behavior change due to restoration activities? Are seals making single, brief feeding runs into the river, or are they resident in the system?	Increased numbers of mammals could be expected to spend more time foraging in, and near the river and have higher reproductive success due to both increased forage and fitness due to increased nutrient quality.	• Observation, scent and camera stations, aerial surveys, winter tracking surveys, IFW harvest records, 2 years before dam removal and years 2 and 4 post, downstream of Veazie, Bangor, Winterport, Bucksport. • For seals, observations at mouth of river and estuary. • Habitat assessment of use areas (depth, fish species, salinity, temperature, etc.)
Nitrogen signatures in freshwater otters	Does the contribution of sea-run fish to otter diets change?	Marine-derived utrients expected to become more prevalent in mammals as sea-run fish increase in their diet.	• Tissue or blood samples from mammals that spend a majority of their time on and around the river (determined from above) sampled for marine derived nutrients (federal permit required).
Contaminants	Will contaminant loads decrease or increase with changes in hydrology and sediment loads?	With increased flow in impoundments and increased fish in and out migration historic contaminants in the system should decrease.	• Tissue sampling for and contaminants) can be from individuals sampled to ID.

E. Food web structure and marine-derived nutrients

Wilson, K.

Core parameters

Stable isotope signatures (N & C) of focal organisms and annual lake sediments.

Background

An increase in diadromous fishes in the Penobscot, as well as changes in distribution of resident fishes, would result in changes in food web structure and nutrient sources over time. In Pacific river systems, anadromous fishes import marine-derived nutrients to freshwater ecosystems through excretion, gametes, and carcasses, contributing to periphyton, invertebrate, and juvenile salmon production (Bilby *et al.* 1996; Cederholm *et al.* 1999; Schindler *et al.* 2003). These nutrients may be subsumed into freshwater food webs through a top-down pathway, i.e., direct consumption of fish prey, or a bottom-up pathway, i.e., marine nutrients and tissues are made available through the decomposition action of bacteria, fungi, or invertebrate scavengers. Similar pathways have not been well elucidated for Atlantic salmon and other co-evolved East Coast diadromous fishes (e.g., clupeids, sea lamprey, eel), but existing research does suggest the potential for marine-derived nutrients to be incorporated into freshwater ecosystems (Garman and Macko 1998; MacAvoy *et al.* 2000; Nislow *et al.* 2004).

Analysis of naturally occurring stable isotopes is commonly used to quantify food web structure, e.g., assign ‘trophic position,’ and track additions of nitrogen and carbon from remote sources. Marine consumers are more enriched in the heavier ^{15}N isotope relative to freshwater consumers because nitrogen is not limiting in freshwater systems and primary producers can and do preferentially take up the lighter ^{14}N. Under limiting N conditions such as in the ocean, primary producers often do not have this luxury and take up the more energetically sluggish ^{15}N as well. Thus marine organisms are generally enriched in the ^{15}N isotope. In addition, ^{15}N is less likely to be excreted and thus bioaccumulates. For example, the muscle tissues of a shark will have a higher ^{15}N signature than those of an alewife, just as the muscle tissues of a bass will have a higher ^{15}N signature than those of a minnow. When a bass eats sea-run alewives, however, one would expect bass to have an N^{15} signature elevated above that of a bass from the same lake eating only minnows. Comparison of freshwater organisms with and without access to marine-derived nitrogen has been used with success in detecting marine inputs to freshwater food webs.

Carbon’s stable isotopes can be used to assess the ultimate photosynthetic pathway through which carbon enters a food web, either through terrestrial leaf litter (allochthonous) pathways, as is often found in streams and rivers, or through atmospheric deposition and internal cycling (autochthonous) as is often found in lakes and reservoirs. Lake food webs have lower ^{13}C ratios than river food webs. Because of this difference one might expect tissues samples from organisms in a food web in impounded stretches of a river to have lower ^{13}C signatures. At the same time, marine-derived carbon is enriched in ^{13}C relative to freshwater or terrestrially carbon. Carbon and nitrogen isotopic ratios are often presented together to show carbon source as well as trophic level. Generally, the ratio of ^{15}N increases ~ 3.4 units per trophic level while ^{13}C remains generally the same. The stable isotope signature of many tissues changes on the order of weeks to months, and in some cases years. Stable isotope analyses are versatile and can present an integrated long-term picture of food web structure or a seasonal picture. Stable isotope analysis complements other food web techniques, in particular diet studies that alone require considerable replication to adequately characterize food web links.

Core parameters	Related questions	Rationale/expectations	Methods
Stable isotope signatures (N & C) of target species **	Does trophic structure shift with the addition of diadromous fishes? What is the contribution of marine-derived nitrogen to the riverine food web ? Quantify the contribution of terrestrial, marsh and phytoplankton primary production to the food web.	Increased availability of small fish prey may increase the trophic position of predator fishes. ^{15}N ratios should increase as diadromous fish runs increase. Increases in ^{15}N may be most pronounced in benthic invertebrates, fast-growing YOY fish, or fast-turnover tissues such as liver (e.g., MacAvoy *et al*. 2001) Loss of phytoplankton productivity associated with impounded areas may shift carbon sources to benthic algae or more terrestrial sources.	• Measure stable isotope signatures (C & N) for at least 10 individuals of a given species and ontogeny (based on size or assumed major prey) in mid- summer, after major spawning runs are complete. • To monitor contributions of marine-derived N to avian predators of anadromous fishes, take blood samples at monthly intervals during spawning runs and analyze for stable isotopes. Isotopic composition of down & feathers of juveniles may also indicate marine derived nutrients.
Stable isotope signatures of annual lake sediments	What is the contribution of marine derived nutrients to annual lake production?	Increases in diadromous fishes (primarily alewife) will increase the ratio of ^{15}N in lake sediments.	• In lakes, monitor stable isotope signature of annual sediments caught using sediment traps.

**Target species: benthic baseline consumers (snails), POM baseline consumers (mussels), benthic invertebrates (multiple functional feeding groups), fishes (resident, non-resident, minnows to apex predators), avian predators, riparian predators (spiders).

F. Human Dimensions

Lewis, L. and J. Banks

NOTE: Recognizing the importance of this subject matter, members of the Trust, Lynn Lewis, and John Banks are continuing to refine and expand this section. Some parameters such as recreational uses of the river, socioeconomic impacts, and cultural and archaeological resources are being addressed through Trust permitting activities.

Background

The human dimensions surrounding the Penobscot River Restoration Project are numerous and enormously complex. The river has immense historical and cultural significance to the Penobscot Indian Nation as well as to more recent residents of the area and the State of Maine. The historical development along the river, including the industrial development of the hydropower dams has both created and destroyed *value*. Economic, psychological, cultural, spiritual and ecological values have all been affected. The economic value of hydropower and the mills has in turn caused the destruction of important economic, aesthetic, and cultural values.

The human values associated with a restoration of this river system are difficult to measure. For example, the intrinsic economic value known as *existence value* is a monetary measure of the willingness to pay to preserve something simply so that it will continue to exist. There is no associated *use* per se. On the other hand, recreational fishery values are somewhat easier to measure using indirect measures such as recreational angler expenditures. The value of water quality can be teased out of property values using hedonic analysis. Commercial values are even easier to measure using market prices. None of these tell the whole story even when simply focusing on the economics. The value of the salmon to the Penobscot Indian Nation, for example, is not measurable in these terms at all. The values are immeasurable. It will be difficult to set up a monitoring plan to assess tribal members "recovery" of cultural/spiritual integrity resulting from a restored Penobscot River ecosystem, nevertheless, this aspect of the human dimension should not be overlooked.

Some of the human dimensions can be captured by observing human behavior, but others are more difficult to measure or observe. The geographical, historical, cultural, aesthetics, economic and emotional features of this system are broad in scope and scale. Intrinsic values are extremely important when looking *ex-post* at a restoration project.

Since the focus of this plan is to monitor the environment surrounding the project at the outset, we simply acknowledge here the scope and magnitude of the human component and suggest that these areas be considered for future research.

Appendix A. Dam Removal Permitting

Anticipated Penobscot River Hydroelectric Dam Removal Permitting Procedures

Federal

1. Once the option is exercised, Penobscot River Restoration Trust must file (a) an application for transfer of the FERC license from PPL to the Trust; and (b) a License Surrender Application to FERC. The license surrender application will include information compiled by the applicant documenting the "existing environment," and provide information on any changes or impacts to resources, including geology, water resources, fisheries resources, wildlife, botanical/wetland resources, cultural and historic resources, land management and aesthetics, recreation resources. The most recent dam removal projects at FERC licensed dams in Maine are the Fort Halifax Dam and the Sandy River Dam,[4] which provide the best indication for expected permitting requirements of the Penobscot dam removals.

After receiving the applications, FERC will prepare a draft Environmental Assessment or Environmental Impact Statement to satisfy requirements of the National Environmental Policy Act (NEPA). It will address each of the areas outlined above. There will be several opportunities for public input, and considerable review by state and federal agencies. A final EA or EIS will be prepared after public comment and agency review.

2. A Clean Water Act Section 404 dredge and fill permit and a Rivers and Harbors Act Section 10 permit are required from the Army Corps of Engineers.

Both of the Federal permits discussed above will trigger consultation under other federal statutes, including the Clean Water Act, the Endangered Species Act, and the National Historic Preservation Act.

State

Removal of hydropower generating or storage dams needs a permit under the Maine Waterway Development and Conservation Act, "the state's one-stop hydropower permitting statute." Approval criteria include (a) making adequate provisions for financial capability and technical capability, public safety and traffic movement, and for mitigating adverse environmental impacts, (b) assuring that water quality standards will be met, and (c) weighing the positive and negative impacts to wetlands, soil stability, fish and wildlife resources, historic and archaeological resources, public rights of access and use of surface waters, flooding, and power generation.

Dam removal is also subject to state water quality certification under Section 401 of the Clean Water Act. The Trust will have to demonstrate that the project "will not result in significant harm to water quality or will not violate applicable water quality standards."[5]

At the local level, dam removal may be subject to local shoreland zoning ordinances and other town development/demolition standards and planning board approval, depending on local ordinances.

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[4] Both projects involved a single dam. The analysis for the Penobscot River Restoration Project will include changes at three dams on the state's largest river.

[5] 38 M.R.S.A. Sec. 635-B.

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