Penobscot River Long-term Ecological Monitoring: DRAFT NOAA Priorities

This report is a work in progress and should not be considered an official policy paper issued by NMFS. Any comments and questions regarding any of the information in this draft are welcomed and should be directed to Rory Saunders at (207) 866-4049 or Rory.Saunders@noaa.gov.

1.0 Introduction

Dams may create impassable barriers for migrating fish, degrade water quality, and negatively alter ecosystem conditions. The socioeconomic costs and ecological impacts posed by dams have led private entities, natural resource professionals, non-profit organizations, and municipalities to seek dam removal as a viable option for diadromous fish and stream restoration (Collins *et al.*, 2007). Common goals for stream barrier removal projects include:

- restoring instream habitat for migratory and resident fishes;
- reconnecting artificially fragmented stream and riparian systems;
- restoring natural flow regimes and stream processes; and
- improving water quality.

In 2004, a coalition of federal, state, and tribal governments and conservation groups signed a settlement agreement with the owner of the two lowermost dams on Maine's Penobscot River that will result in their removal and the construction of a bypass channel around a third dam further upstream. This agreement was pursued primarily to restore diadromous fish runs to the lower Penobscot River basin and accrue the ecosystem benefits associated with dam removals.

Understanding the effectiveness of dam removal requires systematic project monitoring and data reporting. Toward that end, the Penobscot River Science Steering Committee (PRSSC), a diverse group of government agency staff, academic researchers, and non-profit representatives that was initiated by the Penobscot River Restoration Trust in 2005 to organize and oversee scientific research and monitoring related to the Penobscot River Restoration Project (PRRP), has developed a draft Penobscot River Monitoring Framework (PRSSC, 2007). This framework identifies monitoring studies important for understanding long-term ecological response to the dam removals in the lower river. NOAA Fisheries Service and NOAA Restoration Center (collectively referred to as NOAA) are both represented on the PRSSC.

Concurrent to the PRSSC process, but unrelated to it, the NOAA Restoration Center, through the Gulf of Maine Council (GOMC) and in collaboration with state and provincial resource management agencies and non-profit organizations, developed stream barrier removal monitoring guidance for the region (hereafter referred to as the "GOMC guidance"; Collins *et* *al.*, 2007). The monitoring guidance enables evaluating restoration success in these important contexts: hydrology, hydraulics, and sediment; in-stream, wetland, and riparian habitats; and diadromous fish (Collins *et al.*, 2007). To develop the guidance, over 70 experts in these topics were convened in June 2006 for a series of workshops. The group sought to converge on parameters that are integrative—i.e., useful for answering a broad range of questions across disciplines. Participants represented many perspectives including those of resource managers, academics, consultants, and non-governmental organizations (NGOs) in the United States and Canada. Many of the individuals participating in the workshops are also affiliated with the PRSSC.

NOAA recognizes the value of the GOMC guidance in the context of planning long-term ecological monitoring for the PRRP. It is NOAA's view that the critical parameters identified through that multidisciplinary, international effort likely represent the fundamental ecological monitoring needs of the Penobscot project and can form the nucleus of a monitoring program that may include additional parameters. This document describes how NOAA compared the GOMC guidance with the PRSSC draft Penobscot River Monitoring Framework and extracted from it a short list of NOAA Priority Long-term Ecological Monitoring Parameters (or, in some cases, categories of parameters). Also described is the rationale for including each priority parameter on this short list, how to integrate long-term ecological monitoring with permitting and/or feasibility studies, and estimated costs for each parameter.

2.0 DRAFT NOAA Priority Long-term Ecological Monitoring Parameters

To identify priority long-term ecological monitoring parameters, NOAA compared the GOMC guidance with the PRSSC draft Penobscot River Monitoring Framework. Table 1 shows all eight of the monitoring parameters that are identified as "critical" in the GOMC guidance (in some instances these are parameter categories). Also shown are the PRSSC draft Penobscot River Monitoring Framework groups for which there is a "core" parameter that is closely matched to a GOMC guidance critical parameter. It is evident that all of the GOMC guidance critical parameters were also identified as core parameters by the PRSSC. Parameters prioritized by both efforts are clearly valued by the experts involved in these vetting processes and thus are appealing as NOAA priority parameters. The parameters in the shaded rows are the DRAFT NOAA priority monitoring parameters.

Table 1: Long-term monitoring parameters identified by Collins *et al.* (2007) and the PRSSC.

Long-term Monitoring Parameter	GOMC guidance	PRSSC
Monumented cross-sections	critical	Group A
Longitudinal profile	critical	Group A
Grain size distribution	critical	Group A
Photo stations	critical	Group A
Water quality	critical	Group B
Wetland and riparian plant communities	critical	Group D
Benthic macroinvertebrates	critical	Group B
Fish community structure and function	critical	Group E

The only GOMC guidance critical parameter not recommended for further consideration as a NOAA priority parameter is longitudinal profile. Although valuable, repeatedly resurveying the longitudinal profile of the project reach on this large river would be costly and a rough approximation of the longitudinal profile can be obtained from the monumented cross-sections.

There are many other PRSSC core parameters not recommended here as NOAA priority parameters, however the intention is not to diminish their importance or exclude them altogether. These parameters may be considered again for NOAA funding at a later date as the project progresses, but for planning purposes at this juncture, NOAA is prioritizing the parameters listed above because they are most likely to cost-effectively provide the essential information necessary to understand ecosystem response.

3.0 Rationale

3.1 Monumented Cross-Sections

In a long-term ecological monitoring context, cross-section re-surveys will document vertical and horizontal channel adjustments (i.e., degradation, aggradation, widening, narrowing) in response to the new flow and sediment transport regimes following barrier removal. Having the cross-sections monumented also makes them useful as multi-parameter transects at which numerous long-term monitoring parameters can be evaluated. For example, the monumented cross-sections can be the locations where the repeat photo stations are established, grain size distribution evaluated, water quality measurements taken, and wetland and riparian plant communities investigated. They may also be suitable locations for macroinvertebrate and fisheries studies. As multi-parameter transects, the monumented cross-sections are the "skeleton" of the monitoring framework, forming its spatial framework. They can also augment the geometry data in the permitting/design hydraulic model.

3.2 Grain-Size Distribution

Resampling grain size distribution during cross-section re-surveys will document how the composition of the bed material is changing at the cross section over time, and with that information much can be inferred about local changes in the stream's hydraulic characteristics such as roughness and flow competence. These surveys will also provide valuable information about habitat condition for various biota including fish and benthic macroinvertebrates.

3.3 Photo Stations

Repeat photos taken at established, georeferenced locations along the multi-parameter transects can provide a visual record of ecosystem conditions such as riparian vegetation and channel configuration. These conditions may be captured by other parameters, for example vegetation monitoring or channel cross-section elevation surveys, but the photo record provides visual documentation that may be more easily understood by non-specialists. Also, photos capture and integrate in one image a variety of site conditions and in so doing aid the interpretation of other data sets.

3.4 Water Quality

Basic water quality data are critical inputs necessary for assessing and understanding changes in fish habitat use, fish population numbers, and fish community structure and function. Concurrent monitoring (in time and space) of numerous water quality parameters will greatly strengthen our ability to assess the effects of barrier removal/alteration of the Penobscot River fish community. This information will be invaluable for assessing the success or failure of the PRRP towards restoring the Penobscot ecosystem and for the assessment and prioritization of future barrier removal projects.

3.5 Wetland and Riparian Plant Communities

Wetlands and other plant communities in the riparian zone provide a wide array of functions within a riverine ecosystem including: canopy cover to instream and riparian areas; fluvial and slope wash erosion protection; detritus contribution which provides both cover and a food source to instream and terrestrial biota; and transformation or uptake of suspended or dissolved constituents transported to the stream by overland flow or ground water discharge. Since wetlands and other riparian plant communities are strongly influenced, and indeed defined, by local hydrology, characterizing their structure, composition, and function both pre- and post-project is important for understanding the Penobscot River ecosystem's response to the dam removals.

3.6 Benthic Macroinvertebrates

Benthic macroinvertebrate community structure is widely regarded as an important indicator of aquatic ecosystem habitat quality and function. Surveys of the benthic macroinvertebrate community integrate a wide array of chemical and biological parameters because benthic macroinvertebrates have limited mobility, have highly varying tolerances for environmental perturbations, and can be sampled with relative ease. Various metrics of benthic macroinvertebrate community structure have been used to quantify biotic integrity. As an example, the Maine Department of Environmental Protection has used benthic macroinvertebrate communities to assess attainment of water quality standards since 1983.

3.7 Fish Community Structure and Function

The PRRP offers some unique opportunities to reconnect the native suite of diadromous fish with historically accessible freshwater habitats. Current scientific information suggests that a number of ecological linkages (e.g., prey buffers) will also be restored concurrently. However, most of these ecological linkages largely remain untested hypotheses for northeast riverine ecosystems. Large-scale research and monitoring efforts in the Pacific Northwest and Mid-Atlantic states have provided some broad areas that require further testing.

Of particular relevance to the Penobscot are the following general areas: 1) marine-derived nutrients can provide important nutrient subsidies to freshwater and riparian environments; 2) interspecific relations may drive demographic trends of both predators (striped bass) and prey (Atlantic salmon smolts); 3) thorough understanding of abundance levels of diadromous fish populations is requisite to understanding any interactive effects of dam removal. A major hurdle to testing these linkages in a scientifically rigorous way has been the absence of commitments to monitor long-term ecological changes in a restored system. Thus, the Penobscot offers unique opportunities to collect baseline data before, during, and after treatment (i.e., diadromous fish restoration) to truly understand the ecological effects of a large scale dam removal and fish restoration effort.

4.0 Monitoring Methods, Durations, and Estimated Costs

Table 2 summarizes NOAA's priority long-term ecological monitoring parameters including tentative estimates for monitoring methods, durations, and annual costs, among other information. NOAA will continue to refine this information.

5.0 Integration with Permitting and/or Feasibility Studies

As project proponents, NOAA is well positioned to assure that any permitting and/or feasibility studies necessary for project implementation are integrated with long-term ecological monitoring efforts, where such integration is logical and mutually beneficial. For example, there are three field studies occurring in summer/fall 2007 that have direct bearing on the recommended NOAA priorities: detailed bathymetry and sediment characterization studies; freshwater mussel inventories; and a shoreline natural resource and infrastructure assessment.

The detailed bathymetry and sediment characterization studies are a good example of how NOAA is facilitating such integration. The bathymetry and sediment investigations are not only necessary to construct hydraulic models and conduct sediment transport studies required by project regulators, but they are also a prerequisite to identifying the monumented cross-sections that will serve as multi-parameters transects for the long-term ecological monitoring. To make this work useful in the long-term monitoring realm, NOAA will lead an effort to review the ongoing bathymetry and sediment investigations with an aim of identifying these long-term monitoring transects.

NOAA envisions that similar integration is possible for the other ongoing permitting/feasibility studies: the freshwater mussel and shoreline surveys. NOAA intends to continue serving as an important link between the project proponents and the research community.

6.0 Socioeconomic Studies

Socioeconomic factors are critical to consider for river restoration projects generally, and dam removals specifically. Much like the potential ecological benefits of dam removal, little data exists to appropriately evaluate the socioeconomic effects of dam removals. Although not specifically described here, NOAA envisions a variety of socioeconomic studies as part of the monitoring efforts on the Penobscot. We are currently seeking input on core variables of interest and potential partners both internal and external to NOAA.

7.0 Summary and Conclusions

NOAA is committed to evaluating the long-term ecological response of the Lower Penobscot River basin to the dam removals planned as a major component of the PRRP. The response will be physical, chemical, biological, and socioeconomic. The NOAA Priority Long-term Ecological Monitoring Parameters presented in this document, identified by comparing the GOMC guidance with the PRSSC draft Penobscot River Monitoring Framework, cost-effectively provide the essential information necessary to understand ecosystem response. Additional parameters can be added to this core group as needed to support critical research needs, and as funding permits. Proposed monitoring will also take advantage of existing, complementary research underway in the Penobscot basin and adjacent basins.

Annual costs for the full suite of NOAA Priority Long-term Ecological Monitoring Parameters are estimated to be approximately $600,000 to $900,000. Table 2 shows that some parameters require 3-4 years of pre-removal baseline data collection, which suggests that monitoring for those should begin during the 2008 season (assuming dam removal begins in the fall of 2010 at the earliest). Doing so will require monitoring plans and any necessary requests for proposals (RFPs) be developed in the late winter and early spring of 2008.

8.0 References

Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils, 2007. Stream Barrier Removal Monitoring Guide. Gulf of Maine Council on the Marine Environment. Available from http://www.gulfofmaine.org/streambarrierremoval/

Penobscot River Science Steering Committee, 2007. Penobscot River Monitoring Framework. DRAFT.

Table 2: NOAA priority long-term ecological monitoring parameter summaries

Long-term Monitoring Parameter	Core Objective	Key Questions
Hydrodyn., geomorph., and sediment transport	Determine how the PRRP affects hydrodyn., geomorph, and sediment transport in the lower PRB	<u>Has the stream channel geometry changed?</u> Cross-section re-surveys will document vertical and horizontal channel adjustments (i.e., degradation, aggradation, widening, narrowing) in response to the new flow and sediment transport regimes following barrier removal. Results will provide insights regarding the dominant hydraulic and geomorphic processes operating in the reach post-dam removal and indicate the existing, or developing, physical habitat conditions
Hydrodyn., geomorph., and sediment transport	Determine how the PRRP affects hydrodyn., geomorph, and sediment transport in the lower PRB	<u>Has the grain size distribution at the monumented cross-sections changed?</u> Resampling grain size distribution during cross-section re-surveys will document how the composition of the bed material is changing at the cross section over time, and with that information much can be inferred about local changes in the stream's hydraulic characteristics such as roughness and flow competence. These surveys will also provide valuable information about habitat condition for various biota including fish and benthic macroinvertebrates.
Hydrodyn., geomorph., and sediment transport	Determine how the PRRP affects hydrodyn., geomorph, and sediment transport in the lower PRB	<u>What can repeat photos at prescribed stations and bearings tell us about physical processes occurring at the monumented cross-sections?</u> Repeat photos taken at established, georeferenced locations along the multi-parameter transects can provide a visual record of ecosystem conditions such as riparian vegetation and channel configuration. These conditions may be captured by other parameters, for example vegetation monitoring or channel cross-section elevation surveys, but the photo record provides visual documentation that may be more easily understood by non-specialists. Also, photos capture and integrate in one image a variety of site conditions and in so doing aid the interpretation of other data sets.
Water Quality	Determine how the PRRP affects Water Quality in the lower PRB	<u>Has water quality in the lower PN changed?</u> Basic water quality data are critical inputs necessary for assessing and understanding changes in fish habitat, fish population numbers and fish community structure and function. Concurrent monitoring (in time and space) of numerous water quality parameters will greatly strengthen our ability to assess the effects of barrier removal/alteration of the Penobscot River fish community. This information will be invaluable for evaluating the success or failure of the PRRP towards restoring the Penobscot ecosystem and for the assessment and prioritization of future barrier removal projects.
Wetland and riparian plant communities	Determine how the PRRP affects wetland and riparian plant community in the lower PRB	<u>How do riparian habitats respond to drawdown?</u> Wetlands and other plant communities in the riparian zone provide a wide array of functions within a riverine ecosystem including: canopy cover to instream and riparian areas; fluvial and slope wash erosion protection; detritus contribution which provides both cover and a food source to instream and terrestrial biota; and transformation or uptake of suspended or dissolved constituents transported to the stream by overland flow or ground water discharge. Since wetlands and other riparian plant communities are strongly influenced, and indeed defined, by local hydrology, characterizing their structure, composition, and function both pre- and post-project is important for understanding the Penobscot River ecosystem's response to the dam removals.

Long-term Monitoring Parameter	Core Objective	Key Questions
Water Quality		Has the benthic invertebrate community structure changed? Similar to basic water quality data, understanding changes to the benthic community structure due to the PRRP is a critical input necessary for assessing and understanding changes in aquatic community structure and function. Monitoring the Penobscot River benthic community before, during and after the PRRP will allow for the determination if barrier removal leads to changes in terms of abundance, species richness and spatial distribution of the benthic community. This information will be invaluable for interpreting documented changes to the Penobscot River fish community, for evaluating the success or failure of the PRRP towards restoring the Penobscot ecosystem and for the assessment and prioritization of future barrier removal projects.
Fish Communities	Determine how the PRRP affects fish community structure and function	Has fish community structure changed? The PRRP provides and opportunity to understand how riverine fish communities may respond to dam removal/alteration. Monitoring the Penobscot River fish community before, during and after the PRRP will aid in evaluating if barrier removal leads to changes in resident or diadromous fish communities in terms of abundance, species richness and spatial distribution. This information will be invaluable for evaluating the success or failure of the PRRP towards restoring the Penobscot ecosystem and for the assessment and prioritization of future barrier removal projects.
Fish Communities		Has adult abundance of alewives, salmon, shad, eels, and sea lamprey changed? The PRRP offers the unique opportunity to reconnect the native diadromous species complex to their historic habitats in the Penobscot system. Annual monitoring activities are critical to understanding the progress made towards this goal prior to and post barrier removal/alteration.
Fish Communities		Has production of juvenile alosines changed? Restoring the native diadromous species complex to their historic habitats is a major step towards restoring the health of the Penobscot River ecosystem. Establishing self sustaining diadromous populations are required before the full ecological benefits to the system can be realized. Monitoring juvenile alosine production is critical to understanding how quickly and to what extent these populations establish post barrier removal/alteration.
Fish Communities		Has survival of emigrating salmon smolts changed? The National Academy of Sciences stated that the highest priority for restoring the endangered Atlantic salmon in Maine is dam removal. Monitoring emigrating salmon smolt survival prior to and post dam removal/alteration projects is absolutely critical to understanding the benefits afforded by barrier removal/alteration projects towards Atlantic salmon restoration efforts.

Long-term Monitoring Parameter	Core Objective	Key Questions
Fish Communities		<u>Has survival of adult salmon changed?</u> The National Academy of Sciences stated that the highest priority for restoring the endangered Atlantic salmon in Maine is dam removal. Monitoring migrating spawning adult survival from the ocean to their spawning grounds prior to and post dam removal/alteration is absolutely critical to understanding the benefits afforded by barrier removal/alteration projects towards Atlantic salmon restoration efforts.
Fish Communities		<u>Has the distribution of invasive species (e.g. pike) increased?</u> An important concern is potential for increased and accelerated spread of previously established invasive species within the Penobscot River due to the PRRP. Invasive species can have negative effects on the native species complex and could hinder restoration efforts towards re-establishing the native diadromous species complex to their historic habitats. Monitoring the distribution of invasive species will provide critical information on the effects of barrier removal/alteration to their spread and provide information necessary to managed against the potential for negative impacts.
Fish Communities		<u>Have the competitive and predatory impacts of invasive species on native diadromous species changed?</u> Invasive and native species interact in a number of ways, including competition. However, the PRRP could create an environment where the competitive and predatory impacts imparted by the established invasive species prevent the establishment of self sustaining native diadromous populations. If diadromous populations failed to become established, it could be falsely assumed to be a failure of the PRRP. Monitoring the competitive and predatory interaction between invasive and native species is essential to understanding the effects the PRRP has on the fish community of the Penobscot River
Fish Communities		<u>Have the competitive and predatory impacts of native estuarine species on native diadromous species changed?</u> Native estuarine and diadromous species do naturally compete and interact within the Penobscot River estuary. However, the PRRP could create an environment where the balance of the competitive and predatory impacts of these two species complexes hinders the establishment of self sustaining native diadromous populations within newly accessible habitats in the watershed. If diadromous populations failed to become established, it could be falsely assumed to be a failure of the PRRP. Monitoring the competitive and predatory interactions between these two species complexes within the estuary is essential to understanding the effects the PRRP has on the Penobscot fish community.

Long-term Monitoring Parameter	Core Objective	Key Questions
Fish Communities		<u>What are the competitive and predatory impacts of native diadromous species co-existing?</u> Historically, the native diadromous species complex within the Penobscot River co-evolved over time to minimize niche overlap and maximize energy gain per individual. These relations may have provided ecological benefits to some species (e.g. marine-derived nutrients deposition and prey buffering). Attempting to restore this complex to the Penobscot River on a human time scale versus an evolutionary time scale may create an environment where negative competitive interactions out weight the positive benefits obtained from co-existing. Monitoring these interactions will improve our understanding of these processes and will aid in the future management of barrier removal/alteration projects.
Fish Communities		<u>What are the effects on sturgeon dynamics (abundance, survival, distribution, life history…)?</u> Shortnose sturgeon has been listed as endangered since the inception of the ESA in 1973. Little has been known about their status in the Penobscot until recently. Even with new data, abundance levels are still far from clear. Minimally, the upstream distribution for both shortnose and Atlantic sturgeon should be understood. If possible, investigations on the dynamics of these species in these newly accessible habitats should be conducted to understand of the effects of these barrier removal/alteration projects on the species.
Fish Communities		<u>Has the availability and utilization of marine derived nutrients changed?</u> With one goal of the PRRP being to restore the native diadromous fish populations within the Penobscot River, there is an expectation of marine-derived nutrients being imported into the freshwater ecosystem through both top-down and bottom-up pathways. These nutrients may contribute to periphyton, invertebrate and fish communities through increased production and survival. Documenting the addition of nutrients from marine sources and correlating these additions with increases in invertebrate and fish production and survival is critical to understanding the putative benefits of barrier removal/alteration.