

Maine Forest Service

2007

Lower Penobscot River
Stream Barrier Surveys

In Partnership with the
U.S. Fish and Wildlife Service
Gulf of Maine Coastal Program

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Acknowledgements

This report summarizes results of stream barrier surveys and assessments in the lower Penobscot River in 2007, but it represents much more than that. We hope it marks the beginning of an important statewide effort to assess and remove stream barriers across Maine. This project has been the catalyst to developing improved data collection protocols and prioritization techniques for targeting the most critical barriers for removal. My role has been to coordinate the effort, including developing the final survey protocols, providing GIS support and analysis, facilitating meetings and continuing to advocate for greater statewide commitment to barrier inventory and removal work, but I did not begin this project, nor pursue its goals on my own.

The credit for initiating this vital project goes to Chris Martin of the Maine Forest Service and Jed Wright of the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program for believing that this work can and must be done. The National Fish and Wildlife Foundation joined this effort by providing vital funding to the project. And many other individuals have contributed their time and energy to help make this work successful. Thanks are due to Merry Gallagher and Bobby Van Riper of the Maine Department of Inland Fisheries and Wildlife, Jeff Varrichione, Greg Beane and Megan Wooster of the Maine Department of Environmental Protection, Charlie Hebson and Peter Newkirk of the Maine Department of Transportation, Gail Wipplehauser and Melissa Laser of the Maine Department of Marine Resources, Scott Craig of the U.S. Fish and Wildlife Service Ecological Services Office, Josh Royte, Alison Bowden and Doug Bechtel of The Nature Conservancy, Steven Koenig of Project SHARE, Curtis Bohlen of Trout Unlimited, Theo Willis of the University of Southern Maine, and Adam Ogden, the Town of Cumberland's dynamic Public Works Director. Additional thanks are due to Stewart Fefer for his leadership of the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program and encouragement of this important work. The Gulf of Maine Coastal Program was instrumental in this project by providing a variety of resources and technical support throughout.

Special thanks go to all those who have worked hard in the field to collect the data that is the foundation of our work. Rebecca *Reb* Manthey, Theresa Paladino, Bruce Currie and Nicole Bagley spent hundreds of hours assessing road crossings as seasonal staff of the Maine Forest Service. Gayle Zydlewski worked hard coordinating volunteers and collecting data on behalf of the Lower Penobscot Watershed Coalition and Cove Brook Watershed Council. Sarah LaPlante also coordinated and collected data with volunteers and staff of The Nature Conservancy. Many thanks to all of the volunteers who worked to make this project a success, and to the landowners who allowed access to their lands to make this project as comprehensive as possible.

Executive Summary

This report provides a summary of the Lower Penobscot River Stream Barrier Inventory conducted by the Maine Forest Service in cooperation with the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program. The majority of road-stream crossings in the lower Penobscot that rely on culverts pose significant threats to aquatic organisms requiring upstream and downstream passage for access to suitable habitat for spawning, feeding and refuge. These nearly universally undersized culverts not only limit habitat connectivity, but also serve to disrupt other stream processes that are vital to the health of stream ecosystems. The report's findings are not surprising to those who spend a great deal of time in Maine rivers. Barrier's are numerous and will need to be addressed by all who want to improve the health and productivity of our streams.

Our initial ranking has found that of the 533 crossings surveyed in the lower Penobscot drainage, 287 crossings (54%) have been identified as severe barriers to aquatic organism passage. These have been identified as barriers primarily due to structural deficiencies, the most obvious of which are perched outlets at 204 crossings (38%). Some of these crossings would benefit from better maintenance, such as the 93 blocked by sediment, debris or beaver dams.

Culverts that limit aquatic organism passage are most frequently found to be undersized structures. Most of these sites would not meet current design criteria for fish passage. This is primarily due to the fact that culvert design was historically based on hydraulic standards meant only to protect the roadway. Many sites have multiple problems, yet it may take only one structural factor at a crossing to limit passage significantly for many organisms for much of the year. Crossings surveyed include a variety of problems: inlet blockages, inlet drops, perched inlets, perched outlets, shallow water depths, high velocities, and lack of natural substrates.

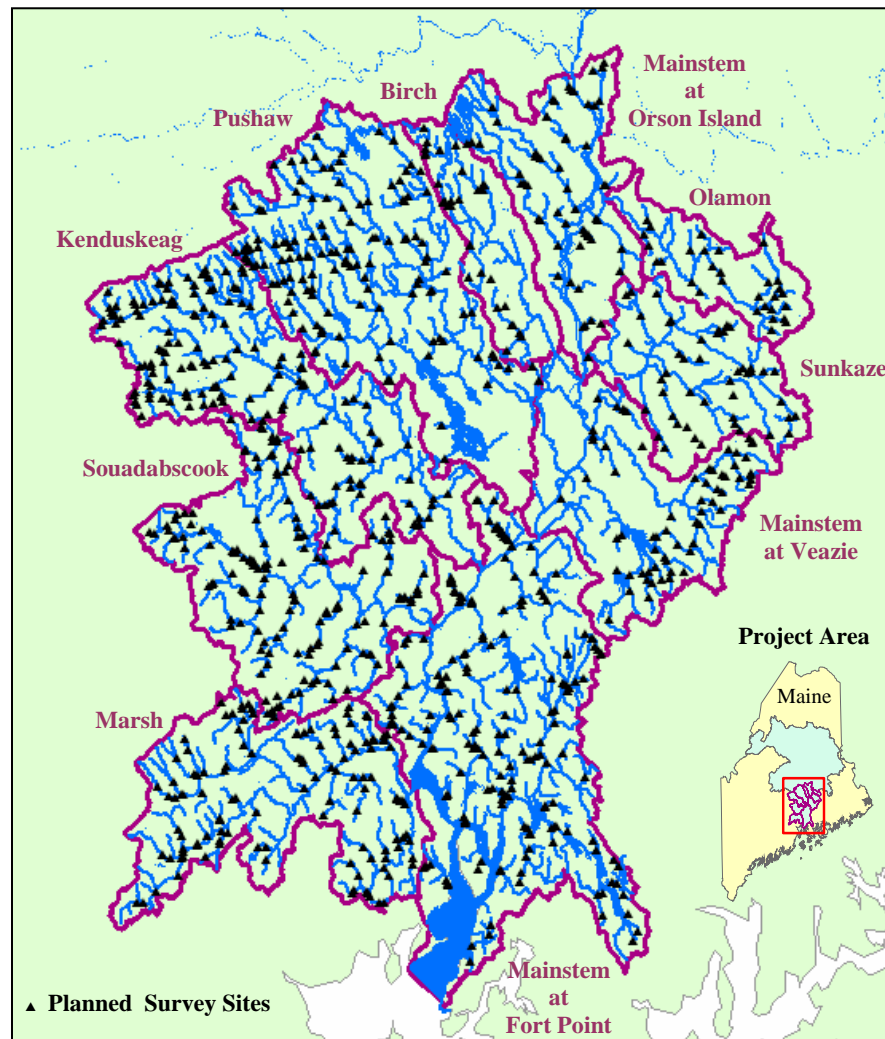
We now understand that a well designed road-stream crossing needs to allow for both transportation and ecosystem functions. The sheer number of crossings with problems point to large replacement costs, but the outlook is not entirely bleak if action is taken soon to begin the process of restoration as opportunities arise. In many cases, the solution is to acknowledge the problem and begin to work to upgrade road-stream crossings. The U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Maine Forest Service, and many other state and federal partners are eager to work with towns, agencies and non-governmental organizations to improve fish passage at crossings. The goal is to accomplish several objectives: to spread the word of why we need to fix these culverts, to demonstrate improvements in crossing designs, to help find funding to share restoration costs, and, in the end, to remove barriers to fish passage in our streams.

Overview

This report provides a summary of the work conducted and data gathered as part of the Lower Penobscot River Stream Barrier Inventory project conducted by the Maine Forest Service (MFS) in partnership with the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program (GOMCP) during 2007.

Project Area

The lower Penobscot River has been identified for the purposes of this project as encompassing the 10 lowest subwatersheds of the Penobscot basin as defined by their U.S. Geological Survey (USGS) 10-digit Hydrologic Unit Codes (HUC-10). The area was chosen particularly for its large quantity of diadromous fish habitat, as well as for its manageable size for survey coverage in one field season. This portion of the watershed was also selected as a focus area in order to build upon fish passage efforts related to the Penobscot River Restoration Project. The total area of 1,523 square miles encompasses approximately 1,176 miles of diadromous fish habitat, 3,500 miles of perennial streams, 1,600 miles of roads and railroad, 36 known dams, and nearly 700 culverts to survey at perennial road-stream crossings.



Background

This project was initiated in 2006 by Chris Martin of the Maine Forest Service Forest Policy and Management Division (MFS) and Jed Wright of the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program (GOMCP) with a request to the National Fish and Wildlife Foundation for funding to inventory barriers to fish passage in Maine streams. Much has been written on the problems posed to passage of aquatic and terrestrial organisms at culverts at road-stream crossings and about the problems posed by dams, but the problem had never been adequately studied in Maine.

Other states have addressed potential barriers at road-stream crossings through field assessments based on survey protocols of their own design. California and Vermont's assessment protocols apply site data to relatively simple algorithms that provide rankings of barrier severity (Taylor & Love, 2001; Vermont Agency of Natural Resources, 2004). Massachusetts and New Hampshire collect field data that is then scored numerically to arrive at similar barrier rankings (Bowden, 2006; Bechtel and Ingraham, 2007). However the data is collected and ranked, it is then available for use in prioritizing removal of barriers through analysis of the data in combination with habitat, land use, water quality or other data.

Many individuals working with state and federal agencies and non-governmental organizations in Maine have been thinking about how to address culverts as potential stream barriers, but have often been overwhelmed by the scale of the problem. We know there are many thousands of culverts in place across the state, and that to replace them all to meet current design standards would cost many millions of dollars. Therefore, it is critical to know which ones act as barriers to the passage of fish and other aquatic organisms. Though some small efforts have been undertaken in Maine to gather this data, they were never coordinated or intended to lead to a statewide barrier inventory. This project played an important role in developing an organized approach to compiling the data and improving decisions to remove stream barriers to benefit fish and the entire ecosystems of which they are part.

This project is meant to support Recommendation II of *Exploring River Restoration Approaches and Needs in Maine* (2004) to develop “a statewide geo-referenced, accessible database of watershed restoration, strategic barriers, fish passage needs and priorities”, as well as the four strategic goals of the *Strategic Plan for the Restoration of Diadromous and Resident Fishes to the Penobscot River* (Laser, 2007):

- (1) coordinating management activities
- (2) providing safe and effective upstream and downstream passage for diadromous and native freshwater fishes
- (3) maintaining or improving abiotic (physical) and biotic habitat for diadromous and selected resident fishes
- (4) using adaptive ecosystem-based management.

While primarily focused on goal two, locating and prioritizing removal of road-stream crossing barriers will also help to accomplish goal three by helping to reconnect streams interrupted by barriers. In addition, by maintaining a database of crossings available to all resource managers, the data from this work will help to accomplish goals one and four, as well.

Development and landscape fragmentation can pose substantial challenges for the management and conservation of the ecosystem services such as watershed connectivity. USDA Forest Service's *Forests on the Edge* report (White, 2006) identified the lower Penobscot Watershed as one of 15 watersheds in the Eastern US as having the highest increase in projected housing density through 2030. Two other adjacent watersheds, the lower Kennebec and Lower Androscoggin River were also identified in this group of 15, distinguishing Maine as the only state with three watersheds expected to see the highest land-use conversion rate from rural to exurban in the eastern U.S. over the next 20 years. Implications to the health of the Gulf of Maine's ecosystem are unknown at this time but one can easily infer increased challenges to watershed conductivity if additional stream crossing structures continue to fall short of existing fish passage performance standards.

Survey Protocol Development

Lacking an existing data collection protocol that was in use by the majority of state, federal or nongovernmental organizations to survey road-stream crossings, the project focused its energies first on developing a protocol that would work for all of the partners involved. At a first organizational meeting in December 2006, several partners agreed to serve on a working group dedicated to establishing a road-stream crossing survey protocol.

Two meetings of the working group were held in the winter of 2007 to develop the framework for field survey protocols. Partners were presented with a summary of attributes collected by protocols in use in Maine and in other states to show similarities and differences. The majority of partners saw the need to develop a protocol that would specifically meet Maine's needs rather than adopt an existing system in use elsewhere. An initial set of attributes was assembled in the first session, and presented in the form of a draft field form at the second session. Once all partners had agreed on the basic goals, structure and content of the field forms, continued review was conducted via email. The working group revised the draft protocol multiple times and a final protocol was released in May as the *Maine Road-Stream Crossing Survey Manual* (Appendix I).

The manual follows the field form with explanations and images to help field crews apply the protocol effectively. The form and manual begins with general site identification attributes, and then moves on to data elements focused on the crossing structure and its setting, including a combination of discrete measurements and qualitative assessments.

Use of the protocol during the first field season has identified a number of areas where modifications will need to be made to the protocols to make them more useful and efficient. We expect an updated edition of the manual will be produced well in advance of 2008 surveys to allow for distribution of the new manual to all those involved in barrier assessment work.

Survey Planning

As protocols for data collection were being developed, a parallel process of field survey planning was underway to prepare for the 2007 field season. MFS hired four seasonal staff members to conduct surveys, providing them office space and support services in their Old Town field office. MFS provided all field equipment needed, including vehicles, digital data collection devices (Trimble Recons), GPS units, digital cameras, and a variety of survey instruments. MFS support staff programmed the Recons to follow the protocol, controlling for errors with drop-down menus and various data entry controls.

GOMCP assisted with survey planning by providing support for geographic information system (GIS) analysis to make surveys as efficient as possible. The first steps taken to this end were to arrive at the set of road-stream crossings to survey. High resolution National Hydrography Dataset (NHDH) streams data were intersected (using Hawth's Tools Intersect Lines tool) by Maine Department of Transportation (MDOT) roads and Maine Office of GIS (MEGIS) transportation (Otrans) railroad data. In total, approximately 1,600 miles of perennial streams were intersected by over 3,500 miles of roads and railroads. Based on work conducted by the Nature Conservancy on the Westfield River of Massachusetts in 2005 and 2006 (Bowden, 2006), we excluded catchments over 30 square miles to avoid survey of larger crossings which tend to be spanned by bridges, and which generally present fewer passage obstacles. A final set of 988 sites was identified for planned surveys.

The second step taken was to create the *Penobscot River Fish Passage Barrier Survey Atlas* (see Appendix II for introductory and selected map pages) to guide field surveys. The atlas provided 161 individual maps indexed by location, map number and town. Each map showed planned survey sites with topography, hydrography and transportation, including road names, to use as a tool to make surveys easier. The atlas was used both to navigate to sites and to record basic data as needed. A companion document listed all survey sites by SiteID with UTM coordinates to verify locations, and provided space for comments. Field crews used the atlas and the site list to record dates of survey, reasons why some sites were not surveyed, and to make additional notes. Additional materials were created to guide subsets of surveys by teams of volunteers within the Marsh Stream subwatershed.

Included in the atlas were three subwatersheds that were used to verify GIS site identifications and to gather a complete dataset of crossings within the area. These *Comprehensive Survey Areas* were selected from all of the 12-digit HUC drainages in the project area to represent three different landscape types. An area in the upper reaches of the French Stream tributary to Kenduskeag stream was selected because of its high proportion of agricultural lands and its inclusion of many headwater streams. Meadow Brook was selected as a more heavily forested subwatershed in the middle of the Marsh Stream drainage, and the last area was selected as a more developed subwatershed at the lower end of Souadabscook Stream. Within each of these three areas, survey crews were asked to look for additional crossings not identified by GIS site selections. Although an additional 83 sites were located in the three special survey areas none of the sites surveyed coincided with perennial streams data, and therefore were not included in the final offset of ranked crossings.

Survey Training

MFS crews were provided with equipment, materials and training to conduct surveys,. Surveyors were given approximately two hours of classroom training to discuss the survey methodology and to review the attributes to be collected. A document containing notes and highlights was given to each surveyor and reviewed in detail. This document contained information on such issues as how to use the *Penobscot River Fish Passage Barrier Survey Atlas* and on safety issues. All crew members were trained in the field by conducting four site surveys to become familiar with the field form (prior to use of the Trimble Recon data collection units) and to practice measurement techniques, with special emphasis on developing sound judgment for making qualitative assessments. Additional training was conducted for Maine Department of Inland Fisheries and Wildlife (MDIFW) staff to add culvert surveys to their brook trout surveys, and a volunteer team leader was trained to be able to train volunteers to support the project within the Marsh Stream subwatershed.

Further training of MFS surveys was conducted after several weeks as part of the project's effort to control data quality. Crews worked to refine their understanding of some of the more challenging survey elements such as the measurement of bankfull channel width.

Outreach

In the spring of 2007, all private landowners who had actively managed their forestlands in the last five years were mailed notices about the surveys to be undertaken, and given the opportunity to ask that surveyors not assess crossings on their land. Also, information was provided about the project in advance in the Small Woodland Owners Association of Maine (SWOAM) newsletter, and a follow-up article appeared later in the year to give an update on the project.

A fact sheet was produced to introduce the project to landowners and others who expressed interest about what the MFS survey crews were doing. The crews had many opportunities to distribute the fact sheets to interested individuals, and to use those occasions to provide information about fish passage at road-stream crossings. In addition, the survey crews learned from many people about the history and current state of the streams in which they were working. Landowners and others continually expressed interest and concern regarding fish passage problems in their local streams, and support for barrier removal efforts.

Barrier Inventory Database

Data collected by MFS survey crews and volunteers was imported to an ESRI Personal Geodatabase (a spatially aware Microsoft Access database) as a table, and then reformatted and edited to correct errors and make records consistent. These records were then plotted as points in ESRI ArcGIS 9.2 software, and edited to correct location and stream coding errors. For instance, several points were found to lie on streams identified in NHD data as intermittent, and so were excluded from the final dataset to be used for stream network analysis.

Further support will allow this database to be the foundation of Maine’s statewide barrier inventory. With additional work to build data entry forms with error controls, the data resulting from other surveys on Mount Desert Island, in the St. George and Presumpscot River watersheds, and surveys conducted as part of the MDIFW brook trout project can be integrated to this database. Plans also exist to combine Maine’s data with data from all other New England states within a database housed at the University of Massachusetts in Amherst as part of the State’s Stream Continuity project. The project will also continue to explore the potential to develop interactive online mapping of barriers in conjunction with related environmental data.

Data Summary

This project has collected large amounts of complex data that is challenging to summarize. One way to look at the data is to see how the number of sites originally planned for surveys was narrowed to the final dataset used for analysis. Table 1 shows the number of planned survey sites, the total number of sites not surveyed, reasons why sites were not surveyed, and the final number of sites used in the analysis. It was somewhat surprising that so many bridges were found by survey crews (22% of planned survey sites), but seemed to confirm that surveys were not *missing* culverts by excluding catchment areas beyond 30 square miles. It may mean that future projects could use a lower standard for excluding catchments likely to have bridges, and thus save time. This data also points up the need make further efforts to survey the nearly 70 sites that were inaccessible to survey crews.

Table 1 Planned, Unsurveyed and Surveyed Sites

	# Sites	%
Planned Survey Sites	988	100
Unsurveyed Sites:	455	46
Bridges considered adequate for fish passage	220	22
No Trespassing	51	5
Abandoned Road	51	5
Culvert Removed	42	4
Inaccessible	18	2
Site does not exist (misidentified by GIS)	30	3
Culvert < 18 inches	22	2
Intermittent Stream	21	2
Lower Penobscot Surveyed Sites	533	54

The 533 sites summarized below in Table 2 indicate that there are significant numbers of road-stream crossings in the survey area that present one or more limitations to aquatic organism passage. Perhaps the most obvious of these limiting factors is a perched outlet. The mean outlet drop for the 204 perched culverts is approximately 8 inches (0.23 m), which represents a

significant impediment for various species and life stages of fish, let alone less mobile organisms. Even more indicative of aquatic organism passage problems is to consider that many crossings have multiple limiting factors at work. For instance, 178 or 87% of the 204 perched outlet culverts also exhibit excessive velocities as judged by their absence of any substrate, and 159 or 78% are also associated with tailwater scour pools indicative of undersized culverts with excessive velocities.

Table 2 provides some simple facts that point to larger issues worth noting. One issue that has concerned many is the apparently more frequent use of sliplining of culverts to save money by inserting a smaller pipe within an older failing culvert. While the concern over increasing velocities and raising the bed elevation of the crossing is entirely valid, the data seem to show that large numbers of new slipliners are not yet occurring in the project area. Another factor brought out by the data is how prevalent public road crossings are (75%). Private roads account for 21% of the crossings, and the remaining sites are all railroad crossings.

Table 2 Surveyed Site Conditions Summary

	# Sites	%
Failed Culverts	5	< 1
Multiple Culverts	122	23
Sliplined Culverts	10	2
Public Road Crossings	402	75
Private Road Crossings	114	21
Railroad Crossings	17	3
Paved Road Crossings	342	64
Blocked Inlets (all)	118	22
Perched Outlets	204	38
Perched Outlets > 0.5 feet	43	8
No Substrate in Culvert	331	62
Large Tailwater Scour Pools	114	21
Culvert Span < 0.5 Bankfull Channel Width	231	43
Culvert Span < 1.0 Bankfull Channel Width	420	79
Lower Penobscot Surveyed Sites	533	100

One way to begin to look at the full set of data on crossings is to place it in its geographic context. Table 3 lists numbers of sites by subwatershed as defined by USGS ten-digit Hydrologic Unit Code (HUC). There are ten such HUC drainages in the project area, listed below with their drainage area in square miles and the amount of linear diadromous fish habitat and pond acreage they contain. The diadromous habitat data was produced by the U.S. Fish and

Wildlife Service Gulf of Maine Coastal Program in partnership with numerous state, federal and non-governmental organizations to represent historic and current extents of habitat for 12 diadromous fish species native to Maine. The numbers of habitat miles listed below indicate the total miles of either historic or current habitat for an assemblage of Atlantic salmon, American shad, and alewife, the three species for which the most data exists, and which were found historically farthest from the mainstem Penobscot. Other species for which there is less data available, including Blueback herring, rainbow smelt, American eel, sea lamprey, and sea-run trout, would likely use much of the same habitat. Not included here are the various important native freshwater species such as brook trout and white sucker that are limited by stream barriers. While the linear measurements of habitat are not as effective for analysis as habitat areas, these data provide a simple measure of habitat to compare drainages.

Table 3 Surveyed Sites and Diadromous Fish Habitat by Subwatershed

Subwatershed	# Sites	Drainage Area mi²	# Sites/ Drainage mi²	Diadromous Habitat Miles	Habitat Miles/ Drainage mi²	Pond Acres	Pond Acres/ Drainage mi²
Birch Stream	14	59.9	0.23	45.5	0.76	271.5	4.53
Kenduskeag Stream	88	191.3	0.46	198.3	1.04	330.5	1.73
Marsh Stream	96	168.7	0.57	92.1	0.55	644.6	3.82
Olamon Stream	17	53.9	0.32	0.0	0.00	39.8	0.74
Mainstem at Orson Island	23	112.7	0.20	126.6	1.12	71.0	0.63
Mainstem at Veazie Dam	34	140.5	0.24	165.0	1.17	2471.1	17.59
Mainstem at Fort Point	96	290.4	0.33	190.7	0.66	7167.2	24.68
Pushaw Stream	67	233.2	0.29	37.9	0.16	6766.5	29.02
Soudabscook Stream	75	177.8	0.42	92.7	0.52	1324.7	7.45
Sunkhaze Stream	23	94.6	0.24	120.3	1.27	77.6	0.82
Total Lower Penobscot	533	1,522.9	0.35	1,069.0	0.70	19,164.6	12.58

Table 3 allows us to observe several interesting relationships. The data has been normalized by drainage area to make comparisons reasonable among subwatersheds. The three columns of normalized data to examine are # Sites/Drainage mi², Habitat Miles/Drainage mi², and Pond Acres/Drainage mi². Comparing each subwatershed's value to the value for all of the lower Penobscot, we can see important differences for each of the three normalized variables.

For instance, Kenduskeag Stream stands out as having a higher density of sites (0.46) and habitat length per square mile (1.04), but a lower number of pond acres per square mile (1.73) compared with the entire drainage (0.35/0.70/12.58)). Its higher road density explains the larger number of sites, while the habitat miles and pond acreage values point to it as a potentially higher priority subwatershed for in-stream habitat and a lower priority for pond-spawning species (alewife, eels). Conversely, Pushaw Stream stands out with lower site density and linear habitat values

than the overall drainage, but has a high pond acreage value because of Pushaw Lake. As a less developed area, we would expect to have a lower density of crossings, but its lack of stream habitat obviously points to other landscape scale issues of hydrology and geology. So, the data in this table can help us to identify important subwatersheds for prioritizing barrier removals based on species groupings (i.e., river-spawners v. pond-spawners) or on intensity of development (higher densities of sites).

Barrier Ranking

In order to set priorities for removal of barriers at road-stream crossings it is necessary to score surveyed crossings by the threat each site poses to aquatic organism passage. Other states and various projects around New England have ranked barriers using a variety of approaches. A common theme among these efforts has been to identify all crossings without passage issues, and then to divide the remaining sites into two or three classes. Normally, the focus is on the class of severe barriers because of their importance in prioritizing barrier removals. There is usually also a class of moderate barriers, sometimes one of minor barriers, and often a class representing crossings that present no barrier.

While some systems rely on numeric scores attached to specific structural factors, this project has focused on the use of a simplified ranking to distinguish the most severe barriers from those crossings that meet the standards of natural channel design and show no sign of blocking passage. All remaining survey sites are ranked as moderate barriers for the purposes of this study because they likely block passage for some organisms at a variety of flows.

Severe barriers are often characterized by a variety of passage issues for aquatic organisms. Outlet drops (perched outlets) and inlet blockages normally involve jump barriers, as well as velocity barriers and problems with turbulence due to flow concentration. Velocity barriers are further made evident by a crossing's lack of natural substrate and the presence of a downstream scour pool. While shallow depths also present significant barriers to many fish attempting to pass road-stream crossings, data was gathered for this project during low-flow periods and has not been adjusted for flow, thus, depth data was not used to rank barriers. For the purposes of this analysis, severe barriers are defined as those structures which have a blocked or perched inlet, or a perched outlet. This standard is meant to identify crossings with the most serious and fundamental structural deficiencies related to aquatic organism passage, and consigns many crossings with potentially significant passage problems to the class of moderate barriers. Failed culverts have been added as a subset of severe barriers needing immediate attention.

Table 4 Barrier Ranking

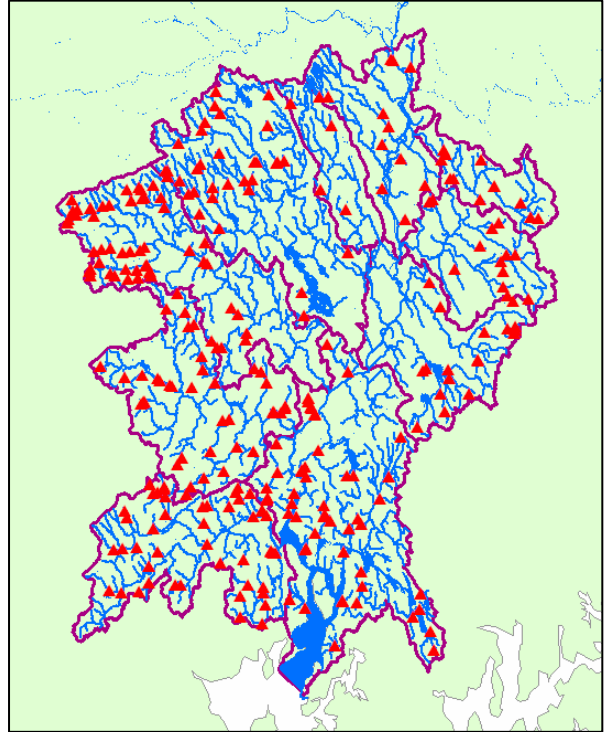
	# Sites	%
Severe Barriers:		
Blocked OR Perched Inlet OR Perched Outlet OR Failed Culvert	287 *	54
Failed Culvert	5	1
Blocked Inlet (significant blockages only)	93	17
Perched Inlet	61	11
Perched Outlet	204	38
Not a Barrier	46	9
Moderate Barrier	198	37
Lower Penobscot Surveyed Sites	533	100

* The total number of severe barriers does not match the sum of the four barrier problems listed below it because for many sites there is more than one factor contributing to their ranking.

In contrast to the severe barriers identified above, there was a small, but important subset of surveyed crossings that present few if any obstacles to aquatic organism passage. A total of 46 sites (9%) present few passage problems. The remaining 198 crossings (37%) represent moderate barriers to passage depending on flows and on which species is being considered. Many of this last subset show evidence of velocity barriers because of a lack of substrate and low span to channel width ratio, and some structures are extremely long given their span (referred to as a low openness ratio, and potentially acting as a light barrier for some species). With some further effort and research, this group of moderate barriers could be broken down into minor and moderate barriers, but these distinctions lose their importance when faced with a significant number of crossings already identified as severe barriers and needing more urgent attention. Table 5 and the accompanying map below provide a simple summary of severe barriers by subwatershed to give a sense of how they are distributed.

Table 5 Severe Barriers by Subwatershed

	# Sites	%
Birch Stream	4	1
Kenduskeag Stream	54	19
Marsh River	47	16
Olamon Stream	12	4
Mainstem at Orson Island	12	4
Mainstem at Veazie Dam	18	6
Mainstem at Fort Point	53	18
Pushaw Stream	33	11
Souadabscook Stream	41	14
Sunkhaze Stream	13	5
Lower Penobscot Surveyed Sites	287	100



Barrier Removal Priorities

The goal of this report is to prioritize removal of severe barriers with respect to existing fish habitat and stream network data to provide clear guidance on which sites should receive high priority for restoring aquatic organism passage in the lower Penobscot drainage.

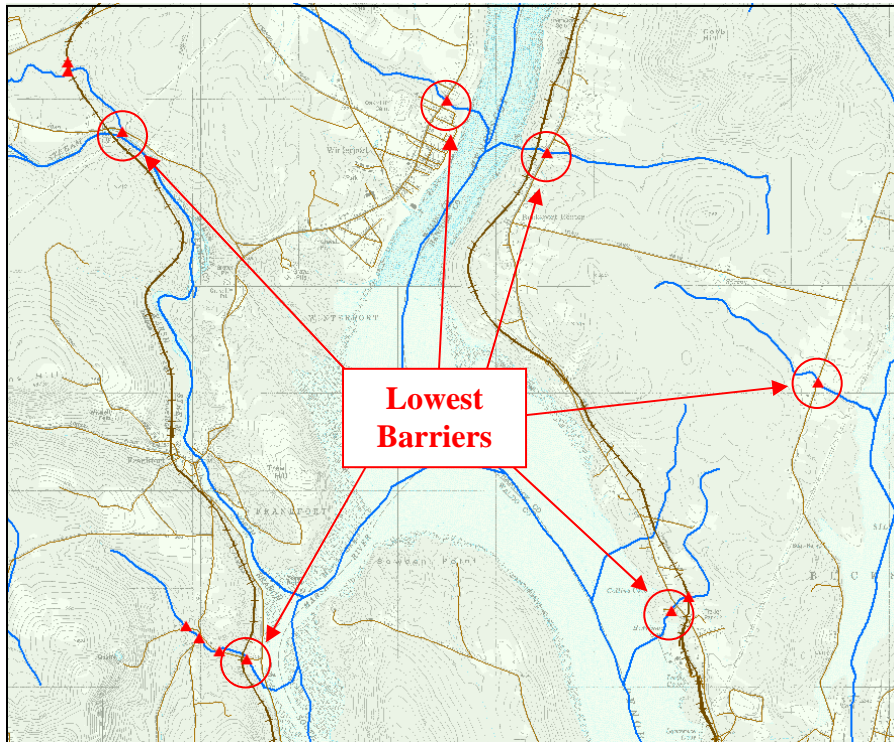
The prioritization approach taken here represents an attempt to balance systematic stream network analysis with the relative lack of species-specific habitat data that would be ideal to identify high priority sites. Species of diadromous and resident fish have different habitat preferences, but the habitat data for diadromous fish currently available focuses on larger streams. Since crossings surveyed through this project have been primarily located on smaller streams, there is little overlap (30%) between the diadromous habitat data and surveyed sites. Given a lack of high resolution habitat data it is necessary to substitute the length of stream that can be opened up with removal of each barrier.

In most cases it makes sense when trying to reconnect stream habitat for diadromous fish to start with the lowest barriers within a stream network. Our prioritization has identified the lowest barriers listed in Table 6. Lowest barriers have been defined here as those crossings downstream of which there are no known severe passage impediments. These lowest barriers take account of any downstream dams, and are only counted as lowest crossing barriers if a downstream dam has at least moderately effective fish passage facilities. That is to say, that all dams were considered to be impassible unless known to provide fish passage. There are twelve impassible dams that act as lowest barriers within the study area, limiting passage to at least 87 severe barriers, leaving all of those inaccessible sites low on the list of priorities for restoration until the downstream dams can be made passable or are removed entirely. Otherwise, all lowest barriers indicated here are

simply the first obstacles faced by upstream migrating diadromous fish. For examples of lowest barriers, see the map image below.

Table 6 Barrier Weighting Factors

	# Sites	%
Lowest Barrier	79	28
Potential Restored Stream Length > 1 mile	37	13
Diadromous Fish Habitat Area	31	11
Lowest Barrier on Diadromous Habitat to Restore Stream Length > 1 mile	6	2
Lower Penobscot Severe Barriers	287	100



After lowest barrier sites were identified, upstream network lengths were calculated to represent potential restored stream lengths for each lowest barrier if removed. Of the total of 287 severe barriers, 79 are lowest barriers with a mean potential restored stream length of 2.6 miles. Of these, 37 are lowest barriers whose removal would open up more than one mile of stream length. Of these sites, only six lie in diadromous fish habitat, and it is these sites, then, that rise to the top of our priority list. Table 7 contains a condensed version of some of the core data developed for each surveyed crossing for the six identified high priority barriers to give a sense of some of the data that can be useful in assessing barrier sites generally.

Table 7 High Priority Barriers – Alternative 1

SiteID	Stream	Town	RoadType1	StructureType	Length Meters	Total Span Meters	Channel Width Meters	Span Ratio
1011	Stubbs Brook	Bucksport	Paved	Mult. Rnd Metal Culvert	20.1	3.99	3.51	1.14
1095	Black Stream	Carmel	Paved	Conc. Box Culvert	8.4	6.1	9.75	0.63
1422	Cove Brook	Winterport	Unpaved	Mult. Rnd Metal Culvert	8.8	2.42	6.71	0.36
1465	Whites Brook	Bucksport	Paved	Mult. Rnd Metal Culvert	26.2	4.19	3.51	1.19
1229	Unnamed	Bucksport	Paved	Conc. Box Culvert	31.7	1.46	4.39	0.33
1683	Birch Stream	T32-MD	Unpaved	Rnd Metal Culvert	13.5	2.26	8.38	0.27

SiteID	Inlet Condition	Outlet Condition	Outlet Perch Meters	Substrate	Total Upstream Miles	Miles Opened	RoadType2	Jurisdiction
	At Grade / Deformed /							
1011	Blocked	Perched	0.06	None	5.9	1.18	Public	Townway
1095	Perched	Perched	0.4	None	27.0	11.20	Public	Townway
1422	At Grade / Deformed	Perched	0.12	None	2.0	2.49	Public	Tnwy sum
1465	At Grade / Blocked	At Grade	0	None	4.9	4.53	Public	Townway
1229	Perched	Perched	1.28	None	1.8	1.85	Public	State hwy
1683	At Grade	Perched	0.12	None	6.5	5.64	Private	priv

One important issue to note in the data above is that one site, #1465, is ranked as a severe barrier because it is blocked at its inlet by debris. Its inlet and outlet are at grade, so it does not pose the same type of restriction to passage that the other sites above do. It may still be undersized, and so become blocked more easily and exhibit higher velocities under many flows than it should, but it does not have permanent structural problems like the others at their inlets and outlets. Unlike those others, site #1465 might be passable with regular maintenance to keep it free of debris. This represents a very inexpensive fix that entails management rather than the costly replacement of the crossing, involving in-depth surveys and construction. Out of the 287 severe barriers, there are 51 that are in this category of “blocked only” crossings.

Though the small number of identified high priority barriers above may seem at first to be a perfect set of priority sites to address immediately, they may not be entirely practical for restoration, however, based on cost of replacement, crossing ownership, or other unforeseen factors that would limit the site’s restoration potential. Given these possible restrictions, there is good reason to develop a larger list of barriers that represent broader opportunities for removal. Because the diadromous fish habitat data exists for only the largest streams and covers a relatively low proportion (30%) of the stream miles surveyed in the lower Penobscot, it is sensible to look at priority barriers without respect to that data to see how such site selections differ.

If we look only at lowest barriers whose removal will open up over one mile of stream length, 37 of the 287 severe barriers represent high priority sites. The previous set of six high priority crossings exists here as a subset, but many more severe barriers block passage to significant numbers of stream miles. Table 8 below provides basic data for these 37 high priority sites.

Table 8 High Priority Barriers – Alternative 2

SiteID	Stream	Town	Structure Type	Inlet Condition	Outlet Condition	Miles Opened	Length Meters	Total Span Meters	Channel Width Meters	Span Ratio
1011	Stubbs Bk.	Bucksport	Mult. Rnd.Metal Culvert	At Grade / Deformed	Perched	1.18	20.1	3.99	3.51	1.14
1018	Birch St.	Lagrange	Rnd. Plastic Culvert	Perched	Perched	3.02	14.0	1.22	19.81	0.06
1039	Burnham Bk.	Garland	Rnd. Metal Culvert	At Stream Grade	Perched	1.13	9.8	1.83	4.05	0.45
1061	Hodge Bk.	Exeter	Mult. Rnd.Metal Culvert	At Grade / Deformed	Perched	2.00	11.0	2.29	42.06	0.05
1083	Unknown	Levant	Mult. Rnd.Conc. Culvert	At Grade / Blocked	At Stream Grade	1.25	17.4	3.19	2.23	1.43
1095	Black St.	Carmel	Conc. Box Culvert Rnd. Metal	Perched At Stream	Perched	11.20	8.4	6.10	9.75	0.63
1101	Unknown	Carmel	Culvert	Grade	Perched	1.38	18.6	1.77	2.16	0.82
1134	Patten St.	Hermon	Rnd. Metal Culvert	At Grade / Blocked	At Stream Grade	5.01	38.1	2.36	6.10	0.39
1152	West Branch Souadabscook	Newburgh	Mult. Rnd.Metal Culvert	At Stream Grade	Perched	3.16	9.8	3.99	3.17	1.26
1209	Unnamed	Stockton Springs	Rnd. Metal Culvert	At Stream Grade	Perched	1.42	14.3	1.22	1.01	99.00
1225	Unnamed	Bucksport	Rnd. Metal Culvert	At Stream Grade	Perched	1.85	22.3	0.76	2.29	0.33
1228	Colby Bk.	Bucksport	Mult. Rnd.Conc. Culvert	Inlet Drop	Perched	1.34	19.8	3.66	3.20	1.14
1229	Unnamed	Bucksport	Conc. Box Culvert	Perched	Perched	1.85	31.7	1.46	4.39	0.33
1246	GoldSt.	Surry	Conc. Box Culvert	Grade	Perched	4.93	13.7	3.05	7.86	0.39
1247	Unknown	Orland	Mult. Rnd.Metal Culvert	At Stream Grade	Perched	3.87	18.3	4.16	40.23	0.10
1257	Clements Bk.	Penobscot	Mult. Rnd.Metal Culvert	At Grade / Deformed	At Stream Grade	1.71	12.2	2.44	1.89	1.29
1302	Crooked Bk.	Charleston	Rnd. Plastic Culvert	Perched	Perched	1.31	12.2	1.16	3.20	0.36
1303	Unnamed	Charleston	Mult. Rnd.Metal Culvert	At Grade / Deformed	At Stream Grade	3.76	9.4	3.86	8.53	0.45
1311	Unnamed	Milford	Mult. Rnd.Metal Culvert	At Grade / Blocked	Perched	1.71	12.2	1.83	14.17	0.13
1340	Allen St.	Exeter	Mult. Rnd. Metal Culvert	At Grade / Blocked	Perched	7.80	11.8	2.21	9.45	0.23
1420	Unnamed	Winterport	Rnd. Metal Culvert	At Grade / Blocked	At Stream Grade	1.97	14.0	3.35	2.56	1.31
1422	Cove Bk.	Winterport	Mult. Rnd.Metal Culvert	At Grade / Deformed	Perched	2.49	8.8	2.42	6.71	0.36
1453	Main St.	Searsport	Mult. Rnd.Metal Culvert	At Grade / Blocked	Perched	1.36	10.1	2.44	3.63	0.67
1465	Whites Bk.	Bucksport	Mult. Rnd.Metal Culvert	At Grade / Blocked	At Stream Grade	4.53	26.2	4.19	3.51	1.19
1538	Unnamed	Orrington	Rnd. Metal Culvert	At Grade / Blocked	At Stream Grade	1.28	22.9	1.22	1.37	0.89
1570	Unnamed	Orrington	Conc. Box Culvert	Grade	Perched	1.05	48.8	1.52	1.74	0.87
1602A	Wheeler St.	Hermon	Mult. Rnd.Plastic Culvert	Perched	Perched	3.53	21.3	1.83	80.77	0.02
1627	Unnamed	Hampden	Metal Pipe Arch Cuvert	At Grade / Blocked	At Stream Grade	4.58	12.2	1.81	5.03	0.36

SiteID	Stream	Town	Structure Type	Inlet Condition	Outlet Condition	Miles Opened	Length Meters	Total Span Meters	Channel Width Meters	Span Ratio
1666	Unnamed	Searsport	Rnd. Metal Culvert	At Grade / Deformed	Perched	1.39	13.7	2.44	4.11	0.59
1680	Wiley Bk.	T32-MD	Rnd. Metal Culvert	At Stream Grade	Perched	2.52	12.8	2.07	4.15	0.50
1683	Birch St.	T32-MD	Rnd. Metal Culvert	At Stream Grade	Perched	5.64	13.5	2.26	8.38	0.27
1719	Unnamed	Orland	Rnd. Metal Culvert	At Grade / Blocked	Perched	1.00	5.8	1.52	3.08	0.49
1739	Unknown	Lagrange	Rnd. Metal Culvert	At Grade / Blocked	At Stream Grade	2.00	8.2	0.46	1.62	0.28
1829	Little Birch St.	Milford	Rnd. Metal Culvert	Deformed / Blocked	At Stream Grade	7.00	11.0	2.16	13.72	0.16
1960	Beaver Bk.	Passadumkeag	Metal Pipe Arch Cuvert	Perched	Perched	4.26	20.7	3.35	4.27	0.78
1968	Rawlins Bk.	Lagrange	Rnd. Metal Culvert	At Grade / Deformed / Blocked	At Stream Grade	1.07	8.2	1.52	35.05	0.04
1999	Unnamed	Milford	Wooden Bridge	At Grade / Blocked	At Stream Grade	2.72	4.7	3.78	25.91	0.15

Earlier in this report, the prevalence of public road-stream crossings in the project area was noted, and this is also generally true for the set of identified severe barriers. Public road-stream crossings account for 70% of severe barriers, private roads for 26%, and railroad crossings for 3%. What these numbers indicate, then, is that private roads are slightly overrepresented in the set of severe barriers.

High Priority Barrier Mapping

This project has as a primary goal to provide towns in the drainage with information about barriers to passage in their jurisdictions. A map of each town (Appendix III) shows the 37 high priority sites listed in Table 8 above, all other surveyed crossings, and also those sites which still need to be surveyed. In conducting the prioritization analysis and creating the maps, no distinction was made between public and private road-stream crossings, though private roads are distinguished from public roads on the maps. Data for each of the severe barriers, including all high priority barriers, is provided in Appendix IV, and organized by town and SiteID. These data sheets summarize the most important data elements for each site. Further data is available by examination of the complete dataset in the barrier inventory database.

Next Steps

Plans are underway to add to the barrier inventory in the mid-Penobscot subwatersheds of the Piscataquis and Passadumkeag Rivers. In 2008, with funding from the National Fish and Wildlife Foundation, the Gulf of Maine Council on the Marine Environment Habitat Restoration Program, the National Oceanic and Atmospheric Administration Community Restoration Program, and the U.S. Fish and Wildlife Service, MFS and GOMCP will again work together to survey road-stream crossings on mid-Penobscot streams, and will also implement several site

restorations based on the data gathered in the lower Penobscot in 2007. These barrier removals will demonstrate the success we can have working in partnership to solve fish passage problems in Maine. The program will increase outreach to local municipalities and agencies based on the results of the inventory and focused on the need to improve fish passage.

Conclusions

There are two important conclusions that we can draw from barrier inventory work on the lower Penobscot River. First, and most critical, is the fact that the majority of road-stream crossings surveyed present fundamental impediments to aquatic organism passage. Second, the methods used for ranking and prioritizing barriers are not highly developed, and depend substantially on the quantity and quality of supporting data available, such as data on fish habitat and on passage requirements by species. Yet, regardless of the methods used, it is clear that there are many barriers in place in the Penobscot drainage, and that the best use of the data collected in road-stream crossing surveys is to apply the most reasonable and comprehensive approach to prioritizing barrier removals, and to begin the restoration process before attempting to gather all possible additional data or refining ranking methods yet further before beginning.

Maine watersheds face important challenges in the years ahead. As noted earlier in this report, its largest drainages, including the Penobscot, face significant development pressures, and they surely contain numerous barriers to aquatic organism passage. We now understand that a well designed road-stream crossings need to allow for both transportation and ecosystem functions. The sheer number of crossings with problems points to large replacement costs, but the outlook is not entirely bleak if action is taken soon to begin the process of restoration as opportunities arise. In many cases, the solution is to acknowledge the problem and begin to work to upgrade road-stream crossings. Standards exist to guide appropriate crossing design, and funding is available to assist with barrier removals

The U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Maine Forest Service, and many other state and federal partners are eager to work with towns, agencies and non-governmental organizations to improve fish passage at crossings. The goal is to accomplish several objectives: to spread the word of why we need to fix these culverts, to demonstrate improvements in crossing designs, to help find funding to share restoration costs, and, in the end, to remove barriers to fish passage in our streams.

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Appendix I: *Maine Road-Stream Crossing Survey Manual*

Appendix II: *Penobscot River Fish Passage
Barrier Survey Atlas*

Selected Map Pages

Appendix III: Penobscot River Fish Passage Barrier Maps

Organized alphabetically by town

Appendix IV: Severe Barrier Data

Organized by Town and SiteID