A Tool for Assessing Connectivity
Dams and Fish in the Northeastern US

Introduction

DAMS and other barriers to the free movement of fish and other aquatic organisms have had a negative impact on the health and viability of these populations for well over a century in the eastern United States. Removing or otherwise mitigating dams can improve the health of aquatic ecosystems and allow fish populations to recover. Given the cost of dam removal projects and the limited funds available to do the work, it is critical that managers focus their efforts and resources where they can have the greatest impact. The Nature Conservancy, in partnership with members of the Northeast Association of Fish and Wildlife Agencies (NEAFWA), has developed a dam assessment dataset and tool for the NEAFWA region (Maine-Virginia). The dataset and tool provide a screening-level assessment of the ecological benefits of dam mitigation. Managers can use the tool to compare the relative benefits of differenet restoration scenarios and narrow their focus and highlight valuable restoration opportunities that may not have been otherwise obvious.

Goals

1. Develop a unified database of barrier information
2. Collect and standardize spatial information of target species presence
3. Produce relative ecological rankings for barriers at multiple scales "Potential Project Benefit Rank"
4. Produce a landscape scale management strategy document

Methods

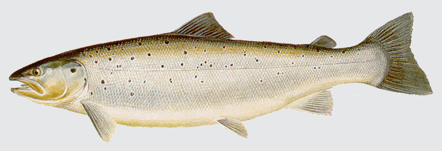
A straightforward sort-and-rank methodology was used to prioritize dams based on their potential to improve aqautic connectivity.

1. Data Preparation: Collection, Processing & Review

Dams -Dam locations and attributes were provided by participating state agencies, the USACE National Inventory of Dams, and the USGS Geographic Names Information System (GNIS)

Waterfalls - Waterfall locations were extracted from the GNIS

Anadromous Fish - Anadromous fish presence data was adapted from the 2006 ASMFC database and assigned to 1:100k NHDPlus hydrography.



Dams and falls were "snapped" to the stream network. Topological precision was necessary for the subsequent analysis

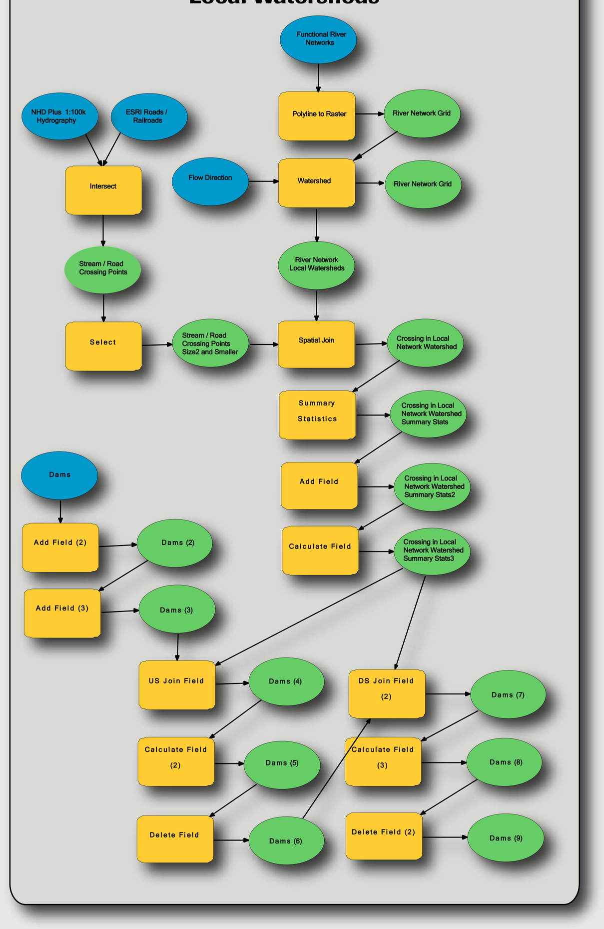
Dams, falls, and fish data were reviewed using a series of automated quality control checkssent to state contacts for additional review / QC

2. Metrics calculated for all dams

A total of 73 metrics from five categories were calculated in a GIS for all dams in the region. Different subsets of the metrics were used in scenarios for anadromous and resident fish species. Metrics were calculated using ArcGIS Model Builder for easy documentation and repeatability.

GIS Model Example:

Density of Road & RR / Small Stream Crossings in Upstream & Downstream Functional Network Local Watersheds



	Metric
Connectivity Status	Upstream Dam Count
	Downstream Dam Count
	Upstream Dam Density
	Downstream Dam Density
	Distance to River Mouth from Dam
	Upstream River Length
	Density of Small (1:24k) Dams in Upstream Functional Network Local Watershed
	Density of Small (1:24k) Dams in Downstream Functional Network Local Watershed
	Density of Road & Railroad / Small Stream Crossings in Upstream Functional Network Local Watershed
	Density of Road & Railroad / Small Stream Crossings in Downstream Functional Network Local Watershed
	Number of Hydro Dams on Downstream Flowpath
	Number of Waterfalls on Downstream Flowpath
Connectivity Improvement	Downstream Functional Network Size
	Upstream Functional Network Size
	The total length of upstream and downstream functional network
	Absolute Gain
	Relative Gain
Watershed and Local Condition	% Impervious Surface in Contributing Watershed
	% Natural LC in Contributing Watershed
	% Agricultural LC in Contributing Watershed
	% Impervious Surface in 100m Buffer of Upstream Functional Network
	% Impervious Surface in 100m Buffer of Downstream Functional Network
	% Natural LC in 100m Buffer of Upstream Functional Network
	% Natural LC in 100m Buffer of Downstream Functional Network
	% Agriculture in 100m Buffer of Upstream Functional Network
	% Agriculture in 100m Buffer of Downstream Functional Network
	% Impervious Surface in ARA of Upstream Functional Network
	% Impervious Surface in ARA of Downstream Functional Network
	% Natural LC in ARA of Upstream Functional Network
	% Natural LC in ARA of Downstream Functional Network
	% Agriculture in ARA of Upstream Functional Network
	% Agriculture in ARA of Downstream Functional Network
	Dam falls on Conserved Land
	% Conserved Land within 100m Buffer of Upstream Functional Network
	% Conserved Land within 100m Buffer of Downstream Functional Network
Ecological Metrics	American Shad habitat in Downstream Functional Network
	Blueback habitat in Downstream Functional Network
	Hickory Shad habitat in Downstream Functional Network
	Alewife habitat in Downstream Functional Network
	Atlantic Sturgeon habitat in Downstream Functional Network
	Striped Bass habitat in Downstream Functional Network
	Atlantic Salmon habitat in Downstream Functional Network
	Number of anadromous species present downstream
	Presence of anadromous species (binary, yes/no)
	Presence of state listed fish and mussel species (S1-S2) in upstream functional network
	Presence of state listed fish and mussel species (S1-S2) in downstream functional network
	Current # of rare (G1-G3) fish species in HUC8 (Max #)
	Current # of rare (G1-G3) mussel species in HUC8 (Max #)
	Current # of rare (G1-G3) crayfish species in HUC8 (Max #)
	Current Likely Presence of Eastern Brook Trout in upstream functional network (EBTJV dataset)
	Current Potential Presence of Eastern Brook Trout in upstream functional network (EBTJV dataset)
	Current Native fish species richness - HUC 8 (Max #)
Size Metrics	River Size Class
	Number of upstream size classes >0.5 miles gained by removal
	Gain in Stream Size Relative to Total Length of Reconnected Functional Network
	Miles Gained of Cold Water Habitat (any stream size)
	Miles Gained of Cold & Transitional Cool Habitat (any stream size)
	Upstream network # of stream sizes
	Upstream Network Miles in Headwaters
	Upstream Network Miles in Creeks
	Upstream Network Miles in Small Rivers
	Upstream Network Miles in Medium Tributary Rivers
	Upstream Network Miles in Medium Mainstem Rivers
	Upstream Network Miles in Large Rivers
	Upstream Network Miles in Great Rivers
	Total Reconnected # stream sizes >0.5 mile (upstream + downstream)
	Total Reconnected Network Miles in Headwaters
	Total Reconnected Network Miles in Creeks
	Total Reconnected Network Miles in Small Rivers
	Total Reconnected Network Miles in Medium Tributary Rivers
	Total Reconnected Network Miles in Medium Mainstem Rivers
	Total Reconnected Network Miles in Large Rivers
	Total Reconnected Network Miles in Great Rivers

Methods

The NEAFWA working group collaborated on developing metric weights

- Not all metrics are of equal importance to aquatic connectivity
- Weights are indicative of the relative importance of a metric to the other metrics (Weight total = 100)
- A subjective aspect to the analysis. Although there is literature to support the importance of connected aquatic habitat to anadromous and resident fish species, there is no literature to support the relative importance of miles of connected network vs. the number of downstream dams to overall aqautic connectiviy. Several iterations of weights were developed through conference calls and review of drafts.

	Metric	Draft Jan. 2011 Anadromous Scenario	Draft Jan. 2011 Resident Scenario
Connectivity Status	Downstream Dam Count	10	
	Upstream Dam Density	3	1
	Downstream Dam Density		1
	Distance to River Mouth from Dam	7	
	Density of Small (1:24k) Dams in Upstream Functional Network Local Watershed	5	3
	Density of Small (1:24k) Dams in Downstream Functional Network Local Watershed		3
	Density of Road & Railroad / Small Stream Crossings in Upstream Functional Network Local Watershed	3	5
	Density of Road & Railroad / Small Stream Crossings in Downstream Functional Network Local Watershed		5
	Number of Hydro Dams on Downstream Flowpath	5	
Conn Imp	Upstream Functional Network Size	20	
	The total length of upstream and downstream functional network		20
	Absolute Gain	5	10
Watershed and Local Condition	% Impervious Surface in Contributing Watershed	3	5
	% Natural LC in Contributing Watershed		5
	% Impervious Surface in ARA of Upstream Functional Network	2	2
	% Impervious Surface in ARA of Downstream Functional Network		2
	% Natural LC in ARA of Upstream Functional Network	5	2
	% Natural LC in ARA of Downstream Functional Network		2
	% Conserved Land within 100m Buffer of Upstream Functional Network		2
	% Conserved Land within 100m Buffer of Downstream Functional Network		2
Ecological Metrics	Number of anadromous species present downstream	5	
	Presence of anadromous species (binary, yes/no)	25	
	Current # of rare (G1-G3) fish species in HUC8 (Max #)		3
	Current # of rare (G1-G3) mussel species in HUC8 (Max #)		3
	Current # of rare (G1-G3) crayfish species in HUC8 (Max #)		1
	Current Likely Presence of Eastern Brook Trout in upstream functional network (EBTJV dataset)		10
	Current Native fish species richness - HUC 8 (Max #)		3
Size Metrics	Number of upstream size classes >0.5 miles gained by removal	2	
	Miles Gained of Cold & Transitional Cool Habitat (any stream size)		5
	Total Reconnected # stream sizes >0.5 mile (upstream + downstream)		5
	Sum of Weights	**100**	**100**

3. Metrics and weights were combined in an Excel tool to calculate a tiered list of dams based on potential ecological benefit rank

A. Data filtered by area of geographic interest (State, HU, region or attribute (e.g. stream size)

Dam Name	US Functional Network Length (m)	DS Functional Network Length (m)
Dam A	239,569	2,572
Dam B	342,665	62,525
Dam C	572,554	6,233
Dam D	125,664	87,425

B. All dams are sequentially ranked for all attributes[1].

Dam Name	US Functional Network Length (rank)	DS Functional Network Length (rank)
Dam A	3	4
Dam B	2	2
Dam C	1	3
Dam D	4	1

C. Ranks are converted to a % scale. This is necessary for "apples-to-apples" comparisons when metric values are not continuous variables

Dam Name	US Functional Network Length (% rank)	DS Functional Network Length (% rank)
Dam A	75	100
Dam B	50	50
Dam C	25	75
Dam D	100	25

D. Mulitply % ran by attribute weight. In this example if US Functional Network Length = 75 DS Functional Network Length = 25

Dam Name	US Functional Network Length	DS Functional Network Length
Dam A	75 * 0.75	100 * 0.25
Dam B	50 * 0.75	50 * 0.25
Dam C	25 * 0.75	75 * 0.25
Dam D	100 * 0.75	25 * 0.25

E. Sum weighted ranks. All metrics which are included (weight >0) are summed to result in a summed rank.

Dam Name	US Functional Network Length (weighted rank)	DS Functional Network Length (weighted rank)
Dam A	56.25	25
Dam B	37.5	12.5
Dam C	18.75	18.75
Dam D	75	6.25

Summed Ranks
81.25
50
37.5
81.25

F. Re-rank summed ranks. The summed ranks are in turn ranked.

Dam Name	Final Ranks
Dam A	3
Dam B	2
Dam C	1
Dam D	3

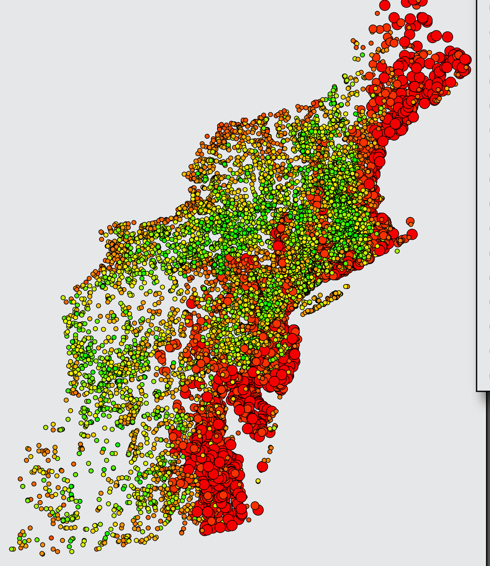
G. The final ranks are sorted for presentation. Additionally, categorical ranks can be calcualted for each dam (e.g. Connectivity Improvement Rank)

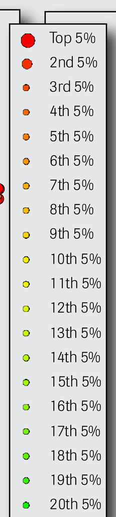
Dam Name	Final Ranks
Dam C	1
Dam B	2
Dam A	3
Dam D	3

[1] Metrics can be ranked in ascending or descending order, depending on whether large values are "good" or "bad". In this example large values are positive factors for anadromous fish -- more network length = more habitat. The values for percent impervious surface in a watershed, for example, would be ranked in the opposite order.

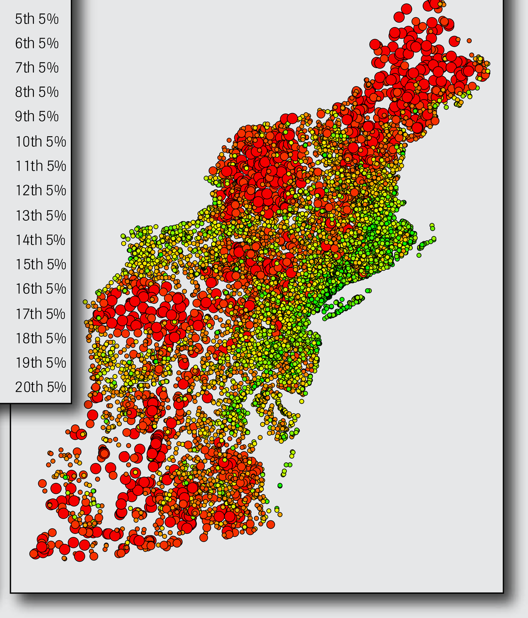
Products

Anadromous Scenario *(draft)*





Resident Scenario *(draft)*

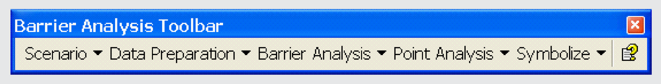


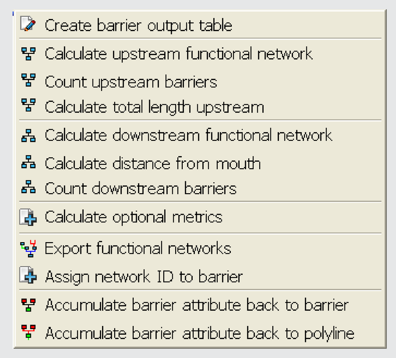
Ranked results were tiered in 5% increments to emphasize that the precise order of the results is not as important as the broad order. (i.e. is a dam with 10.2 miles of network upstream is really different from a dam with 10.1 miles?) This also helps ameliorate imperfections in the data.

Products

In addition to the tiered list of dams, products include the following:

- Excel-based tool which allows managers to re-rank dams using differing spatial scales (e.g. state, HUC) or using attribute filters (e.g. river size class, dam type). Tool also allows for new metric weights to be applied or different metrics to be selected.
- Barrier Analysis Tool (BAT) ArcGIS 9.3 plug-in which facilitates network calculations for dams in GIS. Already being used by partners in several states and Canada.





Outcomes & Challenges

Conservation Outcomes

Through this work, state agencies and conservation practitioners will be empowered to focus their efforts and limited resources on projects that have the greatest potential to result in the increased viability of anadromous fish and resident fish conservation targets. Without this focus on likely results, actors such as OMB are likely to limit federal investment in connectivity restoration. Additionally, by providing a consistent and unbiased regional prioritization, practitioners will be able to better leverage funds to achieve these conservation goals. Moving forward, this project provides a methodological platform which can be built upon and as data improves. In and of itself this project also serves as a catalyst for data improvements.

Limitations and Challenges

With any analysis, the quality of the results is highly dependent on the quality of the input data. This analysis, in which dams are part of a network and are evaluated based on their position within the network, is particularly sensitive to data errors.

Despite efforts to prioritize the dam review process, substantial effort was spent working to improve the data, and more can always be done.

Thus, it is important to note that the analysis results are a starting point for further investigation. They don't provide the definitive answers. They are our best screening -level approximations and need input and verification from people who know the sites and can provide more detailed data on a proposed project's ecology, economics, and feasibility.

Additionally, there can be valid concerns regarding how people might perceive a prioritized list. If too much faith is put in a given list, it can be to the detriment of other worthy projects. Clarity regarding appropriate use of the results is critical (e.g. as a screening tool to help, along with other applicable information, to inform high level planning efforts)

Finally, engaging participants throughout the process is critical. Regular conference calls were held to review project status, solicit feedback from participants, and make key decisions.

Next Steps & Improvements

1. Dam review and metric weight revisions are on-going. Final product, tool, and report are scheduled for completion in early September 2011.
2. Future analyses or work at smaller extents can be performed using *finer resolution* data. In the Chesapeake Bay watershed, approximately 54% of dams in the NEAFWA database snap to the 1:100k hydrography while approximately 82% snap to the 1:24,000 scale hydrography. This provides a more accurate picture of fragmentation on smaller streams. Likewise, if data exists, treating *culverts* as barriers would improve the analysis beyond their current use in summary (non-ranking) metrics.
3. More sophisticated prioritization methods, such as the optimisation models developed in recent years (e.g. O'Hanley and Tomberlin 2005, Zheng 2009), are availble. While not all of the inputs required to run these analyses is available at a regional scale, and computational and programming requirements can be hurdles, they have the potential to improve the prioritization process, particularly in the context of cost.

O'Hanley J.R. & Tomberlin D. (2005) Optimizing the removal of small fish passage barriers. *Environmental Modeling and Assessment* 10, 85–98.

Zheng P.Q., Hobbs B.F. & Koonce J.F. (2009) Optimizing multiple dam removals under multiple objectives: linking tributary habitat and the Lake Erie ecosystem. *Water Resources Research* 45, W12417.

Acknowledgements

Funding for this work was provided by The Northeast Association of Fish and Wildlife Agencies. The authors would also like to thank the NEAFWA workgroup including participants from states agencies in the 13-state NEAFWA region, as well as federal and provincial agencies, NGOs, and universities. Arlene Olivero and Alex Jospe at TNC's Eastern Resource Office spearheaded much of the data preparation work and planning. Finally, Dan Coker at TNC in Maine generously donated the template used for this poster and provided review of earlier drafts.

Erik Martin, The Nature Conservancy
14 Maine St., Suite 401, Brunswick, Maine 04011
(207) 619-3745 emartin@tnc.org

Colin Apse, The Nature Conservancy
14 Maine St., Suite 401, Brunswick, Maine 04011
(207) 373-5291 capse@tnc.org