Measuring Restoration Progress in the PIE-Rivers Region
An Index of Watershed Restoration

Members of the PIE-Rivers Partnership share a common mission; *to protect and restore the valuable aquatic resources of the region*. In order to realize this mission, the PIE-Rivers Steering Committee identified 50 actions that the as near-term opportunities to protect, restore und understand the dynamics of the systems we seek to improve (PIE-Rivers Partnership 2013).

For our efforts to be successful, it is critical that we have a mechanism for tracking progress toward our ultimate goal of healthier, more productive and sustainable aquatic ecosystems and water resources. Ecologically meaningful, easily measured and easily understood metrics are necessary to serve the dual purpose of informing the activities of restoration professionals (including many PIE-Rivers Partners) and engaging participation of influential members of the community (including citizens, officials and funders) who may not have training in ecological restoration or direct knowledge of the issues. Choosing a suite of metrics to track a long-term effort like this is difficult, with inherent tradeoffs between considerations like responsiveness, ability to track trends, relationship to restoration activities, ease of understanding and cost.

The PIE-Rivers region stands out compared with many other watersheds (or groups of watersheds), in part due to the extraordinary ecological and economic value its resources and in part due to the strength and tenacity of the groups that have taken on the task of protecting those resources. Many of the agencies, organizations, academic institutions and municipalities that make up the PIE-Rivers Partnership have been working to protect and better understand the regional ecology for a long time. As a result, we have a good deal of data from historical and ongoing research efforts including university research, agency studies and citizen science campaigns.

Post-implementation monitoring is widely accepted as a critical component of restoration efforts, but is often difficult to fund. This is especially true in cases where there is a need to assess trends over a period of decades. With this in mind, we have developed a suite of metrics to track restoration progress in the PIE-Rivers Region that builds upon and complements the efforts of our partners by interpreting and combining results from a variety of sources. We propose supplemental research or expanded data collection efforts as necessary and leave open the opportunity to add new metrics should new information become available or new needs become apparent. This approach produces a flexible, cost –effective restoration index that can serve as an easily adaptable model for efforts in other watersheds or by other regional partnerships.

We have kept the overall number of metrics small and each metric simple to calculate, track and understand. In many cases, we have simplified the way we present quantitative metrics, such as flow and fish abundance, so that they are easier to interpret with qualitative or semi-quantitative outputs. We will use these parameters to track general trends and say whether conditions are improving or deteriorating through time and as a result of the Partnership's efforts.

Below, we have outlined each of the 18 metrics we will track. The metrics are grouped into seven primary categories that will remain constant through the years. The steering committee may choose to add additional metrics within the categories in response to future needs and/or opportunities.

Table 1. Summary of restoration metrics to be tracked in the PIE-Rivers Restoration Index (continued on next page).

Group	Metric	Sub-metric	Availability	Frequency	Response Variable
Fish and aquatic animals	River herring counts		PIE	Annual	1.1. Estimated Run Size
	Fluvial Fish (Target Community)		Current: I, Future: PIE	Sporadic ~5 years	1.2. Target-Actual % Generalist Species
	Aquatic Macroinvertebrates		Current: I, Future: PIE	Annual	1.3. Percent Model Affinity
			Current: I, Future: PIE	Annual	1.3. Modified Family Biotic Index
Commercial and consumptive fisheries	Shellfish permanently closed areas		PIE	Annual	2.1. Closed area (acres)
	Shellfish temporarily closed areas (rainfall)		PIE	Annual	2.2. Closed area (acres)
			PIE	Annual	2.3. Days Closed (count)
Water quality	Aquatic Life Use		PIE	Sporadic ~10-15 years	3.1. Percent of assessed river habitat meeting standards
			PIE	Sporadic ~10-15 years	3.1. Percent of assessed lake/pond habitat meeting standards
	Fecal Coliform		PIE	Monthly	3.2. Number FC organisms per 100 ml
			PIE	Annual	3.2. Median Number FC organisms per 100 ml
	Dissolved oxygen concentration		PI	Variable	3.3. Annual Mean DO (mg/L)
			PI	Variable	3.3. Quarterly Mean DO (mg/L)
	Dissolved nitrogen concentration		PI	Continuous	3.4. Concentration of biologically available N compounds
Water quantity	Summer Streamflow		PI	Continuous	4.1. Count of summer days (July-Sept) below ecological streamflow threshold
	Municipal water use	Per capita water use	PI	Annual	4.2.1. Annual per capita water use (gallons)
		Total water withdrawals	PI	Annual	4.2.2. Monthly water withdrawals (million gallons/day - MGD)
			PI	Annual	4.2.2. Annual water withdrawals (MGD)

Group	Metric	Sub-metric	Availability	Frequency	Response Variable
Land use	Impervious cover		PIE	Periodic	5.1. Percent impervious surfaces
	Protected lands		PIE	Annual	5.2. Percent protected lands
Critical habitat	River connectivity	Structures improved	PIE	Annual	6.1.1. Count of structures removed or upgraded
		Anadromous fish access	PIE	Annual	6.1.2. river accessible to anadromous fish (miles)
			PIE	Annual	6.1.2. spawning pond area accessible
		Resident fish access	PIE	Annual	6.1.3. maximum and mean functional river network (miles)
	Freshwater/Tidal Wetlands		PIE	Annual	6.2. freshwater wetlands reconnected or restored (acres)
			PIE	Annual	6.2. tidal wetlands reconnected or restored (acres)
Management practices/partnership reach	Water Wise practices		PIE	~5 years as needed	7.1. Count of checklist items implemented
	PIE-Rivers Priority Actions		PIE	Annual	7.2. Count of active projects from
			PIE	Annual	7.2. Count of completed (since 2010) projects from action plan
	PIE-Rivers Programs	Workshops and trainings	PIE	Annual	7.3.1. Count of workshops/trainings held
			PIE	Annual	7.3.1. Number of people reached
		Partnership meetings	PIE	Annual	7.3.2. Count of meetings held annually

Metric Detail

Below are brief descriptions and justifications for the metrics that are used in the PIE-Rivers Restoration Index. More detail on individual metrics and metric scores (once available) can be found on the partnership website (pie-rivers.org) or by contacting the Ipswich River Watershed Association.

1. **Fish and aquatic animals**

1.1. River Herring Counts – Diadromous fish are an important component of the native ecosystem in the region. River herring in particular are a major focus of restoration efforts and are the best studied of the diadromous fish in the PIE-Rivers region. Annual spawning run estimates are calculated each year based on visual counts in the Parker, Ipswich and Essex watersheds. There is also supplemental migration data available for a wider range of species from periodic fish trapping that has been conducted by the Division of Marine Fisheries.

Availability: PIE Frequency: Annual

Response Variable(s): **Estimated Run Size** (corrected for regional inter-annual variability)

1.1.1. Diadromous Fish Observations (Other Species) – We will also summarize observations of other diadromous species as information is available. This will include qualitative summaries and distributions of diadromous fish observations during herring counts as well as incidental observations by anglers and other citizens.

1.2. Fluvial Fish Community Structure (Target Fish Community) – Fish community structure can be an important indicator of a well functioning aquatic ecosystem. Well functioning river systems should support a wide range of fishes including a diversity of habitat generalist and specialist species. Highly impacted systems tend to be dominated by species that are more generalist in their life histories and can tolerate wider ranges of temperature, oxygen availability and pollution levels. Studies in the Ipswich and other Massachusetts Rivers have shown links between water withdrawals and reduced abundance of fluvial (flow dependent) fish species (D. S. Armstrong et al. 2011). Target fish communities are a tool to allow for comparison between current community structure and what would be expected in a minimally impacted system (Bain & Meixler 2008). In 2001, a task group of experts developed a target fish community for the Ipswich River Watershed (Lang et al. 2001). A comparison of that target community and the community that was observed in 1998-1999 is shown below in figure 1. As restoration efforts progress, we would expect to see the fish community begin to look more like the target fish community.

Availability: I (Easily extrapolated to P, E)

Frequency: Sporadic (should be done every 5 years or so)

Response Variable(s): **Target %MHG – Actual %MHG** (Smaller number will better-closer to target community

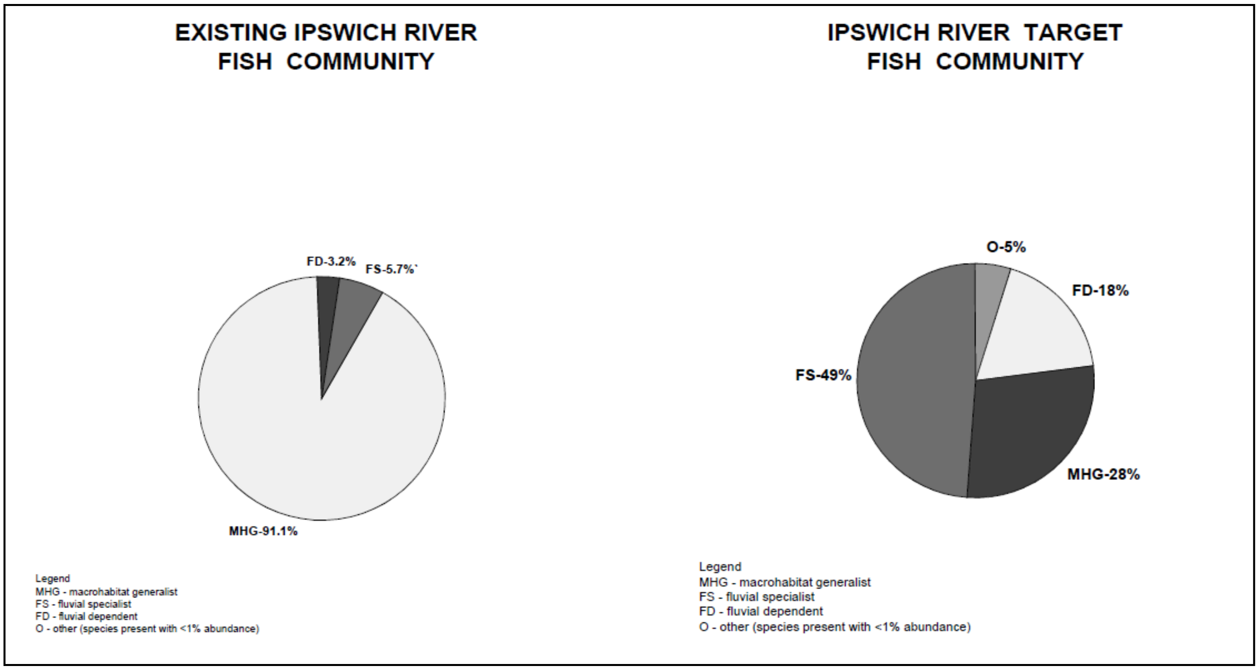

Figure 1. Percent fish community composition by habitat specialty that would be expected in the Ipswich River under natural conditions (Target Fish Community) versus that observed in 1998-1999. (from Lang et al. 2001). The existing fish community is dominated by macrohabitat generalist species and is has very few fluvial fish, indicating a highly altered fish community.

1.3. <u>Aquatic Macroinvertebrate Community Structure</u> – Macroinvertebrates are an important part of the ecology of the region's rivers and are often used as an indicator of overall habitat condition and water quality based on their individual tolerances for parameters like pollution, dissolved oxygen and temperature and their tendency to move relatively short distances during the aquatic phase of their life cycles. The Ipswich River Watershed Association began collecting data at a number of sites in the Ipswich River Watershed since the late 1990s and has been sampling the same sites annually since 2011. We will compile analyze these data and add additional sampling sites throughout the PIE-Rivers region to supplement the coverage in the Ipswich.

Availability: I (Expand to P, E) Frequency: Annual

Response Variable(s): **Percent Model Affinity**; **Modified Family Biotic Index** (Dates & Byrne 1997)

2. **<u>Commercial and consumptive fisheries</u>** – The major consumptive fisheries in the PIE-Rivers region take place in the estuarine portion of the watersheds. The most important of these fisheries is the harvest of bivalve shellfish, including soft-shelled clams. The MA Division of Marine Fisheries and local municipalities manage the fisheries and must close some areas to harvest due to human health risk. These closures are problematic from an economic and social standpoint and are also indicative of watershed scale issues including pollution and stormwater runoff.

2.1. <u>Shellfish permanently closed areas</u> – portions of the PIE-Rivers estuary that are permanently (all year) closed to shellfish harvest for human consumption regardless of weather or water testing results

Availability: PIE Frequency: Annual

Response Variable(s): **Closed area (acres)** – change over time

2.2. <u>Shellfish temporarily closed areas (rainfall)</u> – Shellfish harvest areas that close periodically based on rainfall and water quality data collected by MA Division of Marine Fisheries.

Availability: PIE Frequency: Annual

Response Variable(s): **Closed area (acres)** – change over time

2.3. <u>Shellfish temporary closures (rainfall)</u> - Number of days per year that temporarily closed areas are closed in response to rainfall events.

Availability: PIE Frequency: Annual

Response Variable(s): **Days Closed (count)**

3. <u>Water quality</u>

3.1. <u>Aquatic Life Use Water Quality Assessment</u> – MA Department of Environmental Protection publishes periodic water quality assessment reports for individual watersheds within the Commonwealth. These reports use available water quality information to classify river segments and lakes/ponds based their ability to support designated uses as defined in the SWQS. The designated uses, where applicable, include: *Aquatic Life, Fish Consumption, Drinking Water, Shellfish Harvesting, Primary and Secondary Contact Recreation and Aesthetics* (Carr 2010) .

Availability: PIE Frequency: once every 10-15 years

Response Variable(s): **% of Assessed river habitat (miles)** meeting the standards for Aquatic Life use; **% of Assessed pond/lake habitat (acres)** meeting the standards for Aquatic Life use

3.2. <u>Fecal Coliform</u> – The MA Division of Marine Fisheries measures levels of fecal coliform bacteria present in estuarine waters as part of its shellfish monitoring program. These measurements are taken monthly during dry weather periods in the PIE-Rivers estuary. We will utilize the results from the sampling locations that are closest to the discharge points of the individual watersheds as an indicator of water quality in those watersheds.

Availability: PIE Frequency: Monthly

Response Variable(s): **# FC organisms per 100 ml (monthly); annual median # FC organisms per 100 ml**

3.3. <u>Dissolved oxygen concentration</u> – Dissolved oxygen (DO) is a critical variable governing the ability of aquatic organisms to survive and thrive. Low dissolved oxygen levels can result from a variety of causes including high water temperature, eutrophication and low flow. The Ipswich River Watershed Association, Plum Island Estuary Long Term Ecological Research Station (LTER) and other partners have monitored DO at a variety of sites over the past 15+ years. We will collect and analyze the oxygen data from these various sources to investigate trends in DO concentration in each of the watersheds on a quarterly basis.

Availability: PI Frequency: Variable (monthly in the Ipswich)

Response Variable(s): **Mean (annual and quarterly) DO concentration (mg/L)** by watershed

3.4. <u>Dissolved nitrogen concentration</u> – Biologically available nitrogen is a nutrient that is a common cause of eutrophication and is often an indicator of upstream land use practices and ecological function (e.g. biological processing of nitrogen). Researchers at the University of New Hampshire and the Plum Island LTER have been monitoring nitrogen concentrations at the lowermost dams on the Parker and Ipswich Rivers since 1993 providing a long-term data set on this parameter.

Availability: PI Frequency: Continuous (automatic sampling)

Response Variable(s): **Concentration of biologically available N compounds**

4. <u>Water quantity</u> – One of the major ecological stressors facing the PIE-Rivers region is frequent low stream flow conditions. This is of particular note in parts of the Parker and Ipswich watersheds where flows can be reduced to levels that dewater habitat, raise water temperatures, drive DO below critical levels, and harm wildlife and human uses of the rivers. These problems tend to be most acute during the naturally hotter and dryer summer months of July-September when evaporation rates and human water demand are at their highest. The success of ecological restoration efforts in the PIE-Rivers region depends heavily on the restoration of more natural streamflows in these flow-stressed watersheds.

4.1. <u>Summer Streamflow</u> – A US Geological Survey (USGS) study in the Ipswich River basin proposed a threshold below which summer streamflows become ecologically damaging based on the dewatering of important stream habitat (D. S. Armstrong et al. 2001). While this threshold of 0.42 CFSM (cubic feet per second of water per square mile of watershed) was developed specifically for the Ipswich, we believe it is reasonable to apply the same threshold for evaluating conditions in the Parker an Essex watersheds as well based on their similarities in location, size and character. The USGS operates three realtime streamflow gauges in the PIE-Rivers Region on the Ipswich (2) and Parker (1) Rivers. The MA Division of Ecological Restoration operates an additional 3-6 gauges with operation varying from year to year based on funding and volunteer availability.

*It is worth noting that streamflow is heavily influenced by rainfall and rainfall patterns vary greatly from year to year. Average rainfall and flood frequency in the region has increased measurably since the 1970s (Collins 2009; W. H. Armstrong et al. 2011) and is expected to further change as a result of climate change. We will use available weather data to attempt to normalize flow data for interannual and longer-term variations in rainfall.

Availability: PI Frequency: Continuous (since 1930s for USGS gauges)

Response Variable(s): **Count of summer days (July-Sept) below ecological streamflow threshold**

4.2. Municipal Water Use - Water withdrawals for human use are a major driver of the chronic low-flow problems in the Parker and Ipswich Watersheds. A larger number of municipalities source their water supplies all or in part from groundwater and surface water withdrawals in the PIE-Rivers Region. State-level regulations and enforcement have this far been inadequate to manage the regional water use to protect ecological resources, leaving conservation in the hands of individual towns, citizens and river advocacy groups. Since implementation of conservation measures is decentralized, it is important to summarize efforts and results across the region.

*These data will be collected only for municipalities that source a portion of their water from the Pie-Rivers region and will be summarized by municipality and by source watershed. Municipalities that do not source municipal water from the region are excluded. Municipalities that are located outside of the region, but source water from it (e.g. Salem) are included. Private wells are not monitored and are thus not included in this index.

4.2.1. Per capita water use – This index shows how efficient the average resident is at using water and is a measure of the relative success of conservation measures.

Availability: PIE Frequency: Annual

Response Variable(s): **Annual per capita water use (gallons)**

4.2.2. Total water withdrawals – This index shows overall water use and is a more direct measure of the sum total effect of water use on the watersheds. This is related to per capita water use, but is affected by changes in population.

Availability: PIE Frequency: Annual

Response Variable(s): **Monthly water withdrawals (million gallons/day - MGD); Annual water withdrawals (MGD)**

5. Land use

Land use practices can profoundly affect the ecological conditions in a watershed by altering a variety of parameters including; water quantity, water quality, flood attenuation and habitat conditions for semi-aquatic species. Changes in land use practices tend to occur slowly on a watershed scale and changes in ecological conditions tend to have considerable time lags. In order to understand trends and responses to land use, it is important to look at these parameters over a long period of time.

5.1. Impervious cover – Impervious cover increases stormwater runoff and decreases infiltration often resulting in faster and higher (often referred to as "flashy") peaks in streamflow following rainfall. Increased stormwater and decreased infiltration can also affect watersheds by increasing pollution loads in the river and decreasing groundwater contributions to streamflow (baseflow). Higher percentages of impervious cover in a watershed have been linked to decreased presence and abundance of fluvial fish species in Massachusetts (D. S. Armstrong et al. 2011).

Availability: PIE

Frequency: Periodic – (Mass GIS Updates data every few years, Plum Island LTER and Clark University recently re-analyzed aerial photos for land cover)

Response Variable(s): **Percent Impervious surfaces** in watershed

5.2. Protected Lands – Protecting land against development is the best mechanism to protect against unfavorable changes in land use cover (e.g. creating impervious surfaces) over the long-term. Tracking the extent of permanently protected lands serves as an index to show the how well positioned the region is to guard against future changes in land use that may impact ecological resources.

Availability: PIE Frequency: Annual or as changes occur

Response Variable(s): **Percent Protected Lands** (fee or conservation restrictions) in watershed categorized by whether lands are designated as Core Habitat or Critical Natural Landscapes in BioMap2 (Woolsey et al. 2010)

6. Critical habitat – The PIE-Rivers region provides critical habitat for a wide range of species and ecological communities. Our monitoring efforts will focus on assessing changes in habitat connectivity and mapped habitat for rare species.

6.1. River connectivity – Well-connected river and stream networks are important to allow migration of organisms between important habitats and to promote natural hydrologic and geomorphic processes. Dams and improperly designed road-stream crossings (bridges and culverts) create discontinuities in the natural stream network that can limit species distributions, degrade habitat and exacerbate flooding and/or water quality problems. The PIE-Rivers region has more than 80 dams and 1200 road-stream crossings. The extent of impacts from road-stream crossings is not currently known, but a survey is underway (Funded by the Massachusetts Environmental Trust to be completed in 2014) to survey the crossings in the region and develop a baseline river continuity map. The river continuity map which will include dams and road-stream crossings will serve as a baseline to judge improvements in river connectivity over time.

6.1.1. Structures Removed/Upgraded – Number of barriers that have been removed or had improved fish passage installed

Availability: PIE

Frequency: Baseline survey underway. Afterwards an annual census of restoration efforts and culvert renovations will be used to track changes from baseline.

Response Variable(s): **Count** of dam removals, culverts improved, fish passage installed

6.1.2. Anadromous Fish Access – Measure of habitat access to spawning/rearing areas for anadromous fish.

Availability: PIE

Frequency: Baseline survey underway. Afterwards an annual census of restoration efforts and culvert renovations will be used to track changes from baseline.

Response Variable(s): **river accessible to anadromous fish (miles); spawning pond area accessible to anadromous alewife (acres)**

6.1.3. Resident Fish Access – Measures of how well-connected the watersheds are for freshwater fish species migrating within the watersheds.

Availability: PIE

Frequency: Baseline survey underway. Afterwards an annual census of restoration efforts and culvert renovations will be used to track changes from baseline.

Response Variable(s): **maximum and mean functional river network (miles)**(Martin & Apse 2011)

6.2. Freshwater and Tidal Wetland Reconnection/Restoration– Many freshwater and tidal wetland ecosystems are cut off from or improperly connected to the waterways they were historically associated with. This blocks critical biological, hydrologic and geomorphic connections. This metric captures efforts to restore these systems and their functions. In addition to reconnection efforts, this metric includes already connected wetlands that are structurally restored to facilitate natural hydrology.

Availability: PIE Frequency: Annual

Response Variable(s): **freshwater wetlands reconnected or restored (acres)**; **tidal wetlands reconnected or restored (acres)**

7. **Management practices and partnership reach** – Successful restoration and protection of the PIE-Rivers region will rely heavily on a motivated group of partners that are able to stay engaged over a period of years to decades. This will include continued and increased involvement of a wide range of NGOs, agencies, municipalities, academic institutions and citizens all working together to implement proactive restoration and conservation measures.
   7.1. Water Wise Practices – The Ipswich River Watershed Association developed the Water Wise Communities handbook to promote water management best management practices among the local municipalities (E. Levin 2006). This handbook provided a checklist of 20 items that municipalities could implement to improve water management and encourage water conservation within their jurisdiction.

   Availability: PIE

   Frequency: Develop baseline, recheck as changes occur or every 5 years

   Response Variable(s): **Count of checklist items implemented** by municipality

   7.2. PIE-Rivers Priority Actions – The PIE-Rivers Partnership has identified 50 priority actions to promote our mission. By keeping track of partners' efforts toward implementing these actions, we can gauge involvement and progress toward our goal and identify areas that need greater focus in future years.

   Availability: PIE Frequency: Summarize Annually

   Response Variable(s): **Count of active and completed (since 2010) projects** summarized by action # and toolkit as described in the Action Plan document (PIE-Rivers Partnership 2013)

   7.3. PIE-Rivers Programs – Visibility and activity by the PIE-Rivers Partnership is important to ensure that our message reaches the right people and we disseminate information to interested parties.
      7.3.1. Workshops and trainings – Hold workshops and trainings promoting restoration actions and best management practices to a variety of audiences

      Response Variable(s): **Count of workshops/trainings** held; **Number of people reached**

      7.3.2. Meetings – Partnership meetings including Steering Committee and Sub-Committee meetings

      Response Variable(s): **Count of meetings held annually**

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