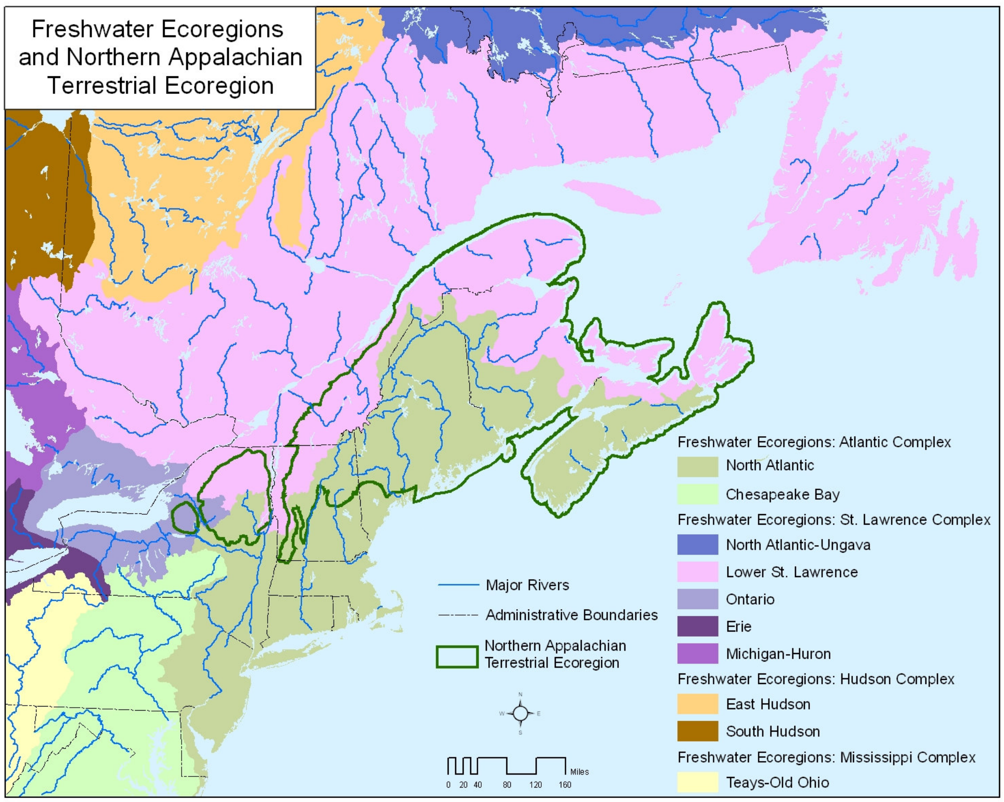
Northern Appalachian Freshwater Stream Ecosystems

3rd Draft 3/15/2006, Anderson: 1/19/2006 A. Olivero

1. Northern Appalachian / Acadian: Freshwater Ecoregions and Basins

The Northern Appalachian / Acadian ecoregion is as well known for its aquatic features as for its mountains and coast. With snowy winters and humid summers, the once glaciated region boasts over 18,000 miles of streams and over 14,000 lakes. Split by the Appalachian mountains, large scale patterns of freshwater diversity correspond to huge drainage basins, the North Atlantic draining south and the St. Lawrence draining north, which have internally similar climatic and historical freshwater linkages.[1] A portion of a third, the Lake Ontario basin, drains west from the Tug Hill plateau in New York (Figure 1).

Figure 1. Map of Freshwater and Terrestrial ecoregions



The North Atlantic Major Drainage Basin: Draining southward, this basin cover half of the ecoregion (81% of the U.S.) and is noted for high quality temperate coastal rivers, numerous lakes, and significant runs of anadromous fish such as Atlantic salmon, shad, and herring. Endangered aquatic fauna include the dwarf wedge and brook floater mussels, Atlantic and shortnose sturgeons and the ringed boghaunter dragonfly. Major rivers include the St. John, St. Croix, Penobscot, Kennebec, Androscoggin, the upper portions and headwaters of the Connecticut, Hudson and Merrimack and the Medway, St. Mary's, and other southerly draining smaller coastal rivers of Nova Scotia.

The St. Lawrence Major Drainage Basin: Draining northward from the mountains to the St Lawrence River, this half of the region (21% of the U.S. portion) has a more cold tolerant fauna and lower freshwater species richness than the North Atlantic drainage (Abell et al. 2002).

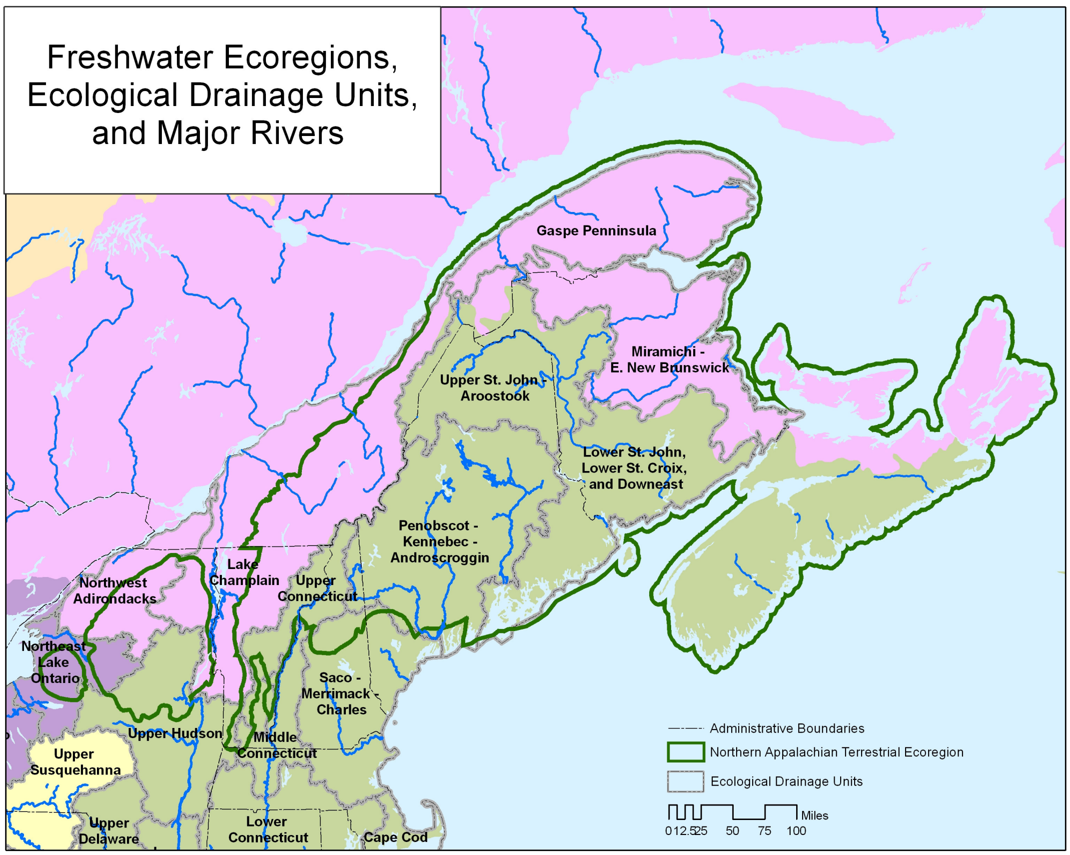
[1]These "freshwater ecoregions" were developed by the World Wildlife Fund (Abell 2002) and make more ecological sense for assessing freshwater features than terrestrially based "ecoregions" .

It is known for numerous lakes including Lake Champlain, Lac Saint-Jean, and Lake Manicouagan, and their large tributaries such as the Missisquoi, Lamoile, Winooski, Otter, Ausable, and Great Chazy along with other rivers draining northwest out of the Adirondacks such as the St. Regis, Raquette, Grass, Osweegatchie, and Indian. Significant self-sustaining runs of anadromous Atlantic salmon occur in the Canadian portion of the basin, which also includes the Upper Saint-Francois, Chaudiere, Rimouski, Matane, Casapedia, and Saint-Jean in Quebec and the Nepisiguit and Miramichi Rivers in New Brunswick.

The Ontario Major Drainage Basin: A small part of the New York Tug Hill region defined by the watershed of Lake Ontario, this basin includes the headwaters of the Black, Saimon-Sanity and Oneida Rivers.

Within the major drainage basins, 12 large watershed units, termed **ecological drainage units** (EDUs) were defined by ecologists based on faunal and geomorphic similarities and used for coarse level freshwater stratification of the region (Figure 2). Note that some, e.g. Merrimack and Middle Connecticut, cover only a small portion of the ecoregion.

Figure 2. Map of Ecological Drainage Units



Watershed Groups within Ecological Drainage Units

Our conservation objective was to conserve the full diversity of riverine species in the ecoregion by focusing on the protection of whole stream ecosystems. Thus, we strove to identify multiple, high-quality examples of each stream type across biogeographic and environmental gradients within the ecoregion (Anderson and Olivero, 2002). To allow for this, we developed a watershed characterization and classification scheme within each EDU, to enable us to identify distinct biophysical settings. Using watershed groups ensured that we could locate streams representing a full spectrum of biophysical settings increasing the likelihood of including all biodiversity in our portfolio networks.

To develop the watershed classification scheme, medium watersheds (30-200 sq.mi. drainage area) and large watersheds (200-1000 sq.mi. drainage area)in the US portion of the ecoregion were assessed as to the abundance and distribution patterns of geologic settings, elevation zones, and landform types within the watershed. Subsequently we grouped the medium watersheds into 49 different watershed groups and the large watersheds into 33 watershed groups. We referred to the watershed groups as "system types" as each delineate geographic areas that are similar in their biophysical structure and, presumably, their ecological processes and associated biodiversity (Figures 3 and 4). The total number of system types (82) is similar to the number of aquatic systems targets in other ecoregions. Details on each watershed system are in Appendix 4.

Figure 3. Map of medium size watersheds in the Northern Appalachian Ecoregion, US portion.

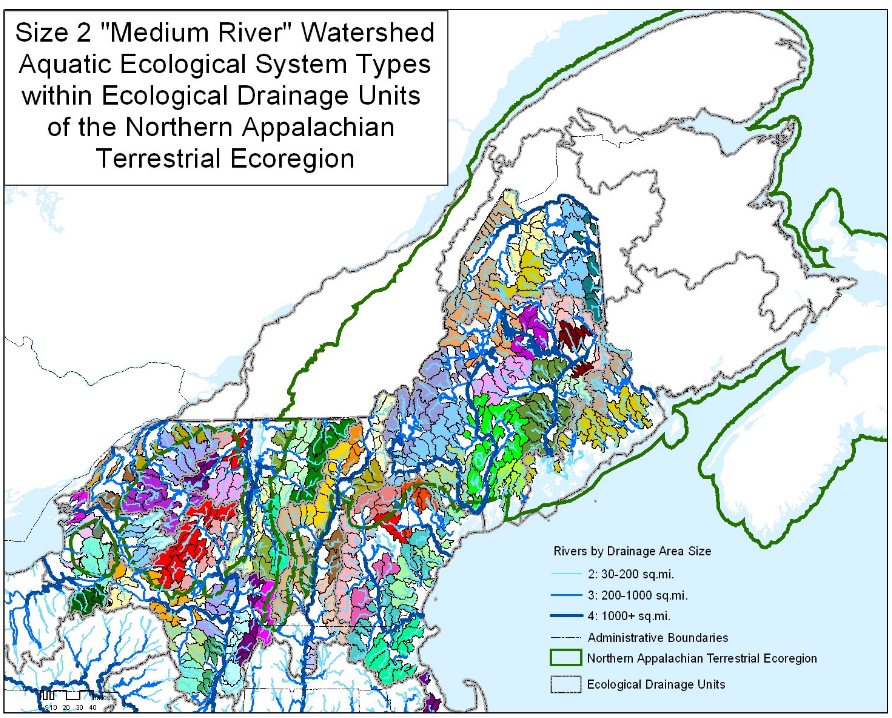
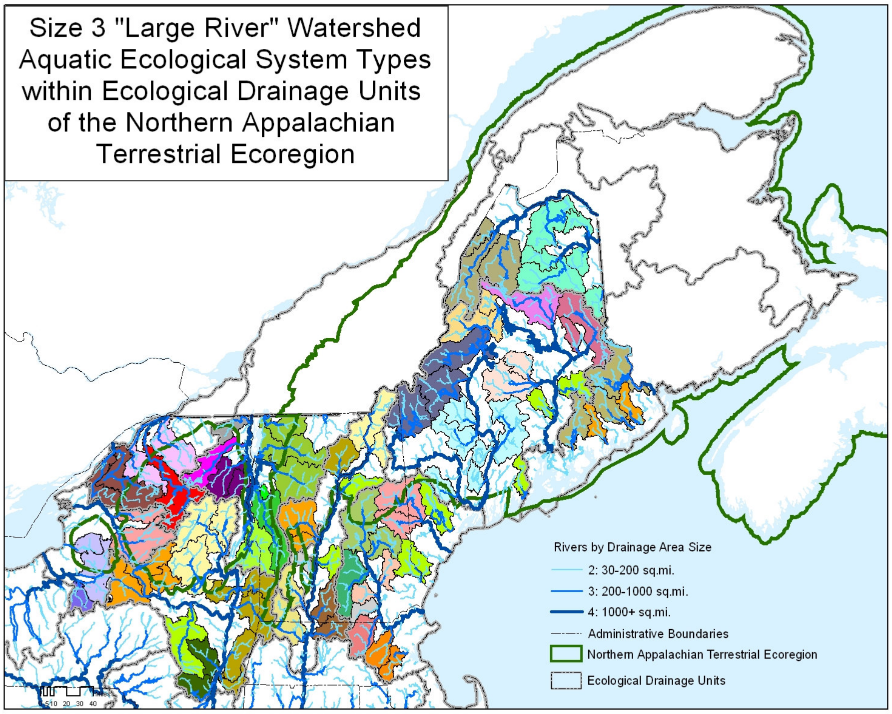


Figure 4. Map of large watersheds in the Northern Appalachian Ecoregion, US portion.



2. Freshwater Biota of the Northern Appalachian / Acadian region

Freshwater rivers, streams, lakes and ponds are diverse, multifaceted systems with a permanent biota comprised of fish, amphibians, crayfish, mussels, worms, sponges, hydras, hydromorphic plants, mosses, algae, insects, diatoms and microscopic protists. Evidence suggests that freshwater communities are organized at many scales corresponding to broad climatic and historic factors as well as local factors such as waterbody size, depth, water velocity, bottom substrate, light penetration, pH, and dissolved oxygen concentrations.

This region's freshwater fauna is estimated to include between 12-20 species of mussels, 6-9 crayfish species, 26-40 herpetofauna, and 90-110 fish species (Abell 2002). Three species of fish (Atlantic whitefish, Blueback trout, and Lake Utopia dwarf smelt) are endemic to the region (Abel et al. 2002. and see Species chapter) Analysis of distribution data suggests that over half of the fish species are widely distributed across all the drainage basins, while others occur only within two (20% of fish species) or one (32% of fish species) of the basins (Appendix 1).

The present freshwater biota results from a relatively recent recolonization of the region following massive extinctions during glaciation (10,000-15,000 years ago). These northern watersheds were disconnected from the species rich southern refugia of the Mississippi basin and there were salt-water barriers to recolonization along the Atlantic slope. Presently freshwater faunal richness is lower than in southern and western North American regions. In contrast, the total number of aquatic plant species is higher in the Northeast U.S. (145 species) than in the Southeastern U.S. (122 species) or in Central America (120 species). Most of this diversity is in the sedge (cyperaceae) and water milfoil (halogoraceae) families (Crow, pers. com.).

Rare Species: Primary and Secondary Targets

Rare and declining species dependent directly on aquatic features in the region include 40 species, mostly plants, but also 6 fish, 3 mussels, and 6 dragonfly species. These have been determined to require individualized protection plans due to their declines or absolute rarity (e.g. they are considered **primary targets**). Another 23 species were identified as **secondary targets,** species of concern that we hope to protect by protecting stream ecosystems rather than individual conservation plans for each species (Appendix 2 – and see the Species section).

Diadromous Fish Species

The ecoregion supports 7 of the 10 diadromous fish species occurring along the northeastern coast between New Brunswick and Cape Hatteras. Although populations of diadromous fish have undergone significant declines across their range, the North Atlantic drainages of this region are noted for containing excellent habitat and a high percentage of the remaining sustaining runs. Atlantic salmon, shortnose sturgeon, and Atlantic sturgeon were considered primary targets and blueback herring, alewife, and American shad were considered secondary targets. American eel, which occurs throughout the region, was not considered a target, but recent declines across their range suggest a reevaluation of this species in future iterations of the plan is warranted.

3. Freshwater Stream Communities

Characteristic Riverine Biota in the Northern Appalachians

The species composition of freshwater streams is correlated with changes in stream size, gradient, elevation, ph, and substrate characteristics. Based on these patterns we recognized five major stream and river types in four size classes (Appendix 3). The size classes were:

- Size 1: 0-30 sq mile watersheds. Bankfull width 0-10 ft. Headwaters and feeder streams
- Size 2: 30-200 sq mile watersheds. Bankfull width 10-20 ft. Moderate-sized streams, often confined.
- Size 3: 200 – 1000 sq mile watersheds. Bankfull width 20-40 ft. Large streams, usually unconfined, meandering
- Size 4: 1000+ sq. mile watersheds; Bankfull width 40 – 100 ft. Large deep rivers

These 4 size classes correspond closely to the following 5 stream types typical of the ecoregion, allowing for overlap particularly between the size 2 and 3 types (modified from Hunt 2003).

1. *Rocky Headwater Stream*: Small, size 1 (order 1-3), cold water streams with high to medium gradients. Predominance of coarse rocky substrate riffle habitat over run habitat. Good aeration and relatively high velocity. Acidic and circumneutral variants. Bryophytes and epilithic green algae predominate. Macroinvertebrates include leaf shredders, and algae shredders. Cold water fish communities. (e.g. Brook Trout, Brook Trout – Slimy Sculplin, Brook Trout-Slimy Sculpin-Blacknose Dace)

2. *Marsh Headwater Stream*: Small, size 1 (order 1-3), meandering streams with very low gradients. Predominance of run habitat over riffle habitat. Fine mucky substrate, poor aeration, low velocity; usually surrounded by wetland communities, typically shrub swamp, emergent marsh or fen. Acidic and circumneutral variants. Cold-cool- warm water. Submergent vascular plants predominate. Macroinvertebrates include characteristic marsh and pool species including

water surface dwelling (neuston) fauna and possibly lake outlet fauna. Possible fish assemblages spanning all microhabitats from cold/cool to warm. (Brook Trout, Slimy Sculpin, and Blacknose Dace, Fallfish, Longnose Dace, Creek Chub, Longnose and White Sucker, Common Shiner, Fathead and Bluntnose Minnow)

3. *Moderate to Large Confined Stream/River*: Size 2 or occasionally larger shallow stream/river (orders 5 to 6) with steep sideslopes in riparian areas that confine the river. Generally moderate to low gradient system with few meanders;. Contains well defined pattern of riffle, run and pool microhabitats with an abundance of riffle microhabitat. Typically cobble shore or riverside sand-gravel bar, coarse substrate (cobble or sand), good aeration, relatively high velocity, prominent erosion and minimal deposition. Circumuentral to moderately acidic pH. Usually without a profundal (dark zone) or hypolimnion or associated obligate species. Epilithic green algae predominate. Plankton assemblages relatively sparce. Macroinvertebrates include algae shredders and neuston fauna in pools and abundant riffle specialist fauna; fauna characteristic of pools and soft bottoms at low abundance. Mussel diversity is generally poor. Fish diversity is typically moderate to high with cool to warm water communities (Brook trout- Slimy Sculpin, Brook Trout – Blacknose Dace, Blacknose Dace-Common Shiner-Bluntnose, Minnow-Creek Chub, Pumpkinseed-Bluntnose Minnow-Tessellated Darter, and White Sucker.

4. *Moderate to Large Unconfined Stream/River*: Size 3 or occasionally larger (orders 5-6), shallow, meandering stream with predominance of run microhabitat and paucity of riffle microhabitat. rivers, The shallowness and absence of a profundal (dark) zone and a hypolimnion separate these rivers from the deep rivers described next. Very low gradient, fine substrate (typically silt), poor aeration, relatively low velocity, circumuentral to moderately acidic pH, prominent deposition and minimal erosion; usually surrounded by wetland communities, typically floodplain forest, often with levees. Vascular plants may be abundant in slower sections, epilithic green algae and phytoplankton may be abundant. Characteristic macroinvertebrates include odonates typical of floodplains. Warm water fish community more dominant: Fish include Blacknose Dace-Common Shiner, Pumpkinseed-Bluntnose Minnow-Tessellated Darter, and White Sucker

5. *Deepwater River:* Size 4 river or very large stream (order 8 or higher) with high discharge, low adjacent canopy cover. Relatively deep (often with portions greater than 4 m deep) and wide (average width over 2 meters) and separated from smaller rivers by the presence of dark profundal zone and possibly a hypolimnion zone hosting corresponding obligate species. Principal nutrient source originating within the stream system (autochthonous). Abundant coarse woody debris, temperature warm; often with lateral erosion, braided channels and substantial deposition. Biota include profundal obligates, bryophytes absent or confined to banks and exposed surfaces, well developed plankton community, fish diversity high to moderate.

Mapping and Characterizing Stream Reaches:

To apply the classification system, and thus map and assess streams throughout the US portion of the ecoregion, we used GIS techniques to characterize every stream reach by its size, gradient, elevation, bedrock, local connectivity and by the biophysical properties of its watershed. (see Olivero 2002 for details)[2].

Distribution patterns were highly skewed towards smaller streams with size 1 streams being five times more common than any other stream type. They were also distributed across all gradient and elevation classes (Figures 3 and 4). In contrast, larger streams were nearly all very-

[2] Further information on our methods in Seelbach et al. 1997, Higgins et al. 1998, and the Missouri Gap Valley Segment Classification 2000)

low gradient features at elevations below 1700 feet (Figure 5 and 6). Large streams were more apt to encounter many bedrock settings while size 1 streams often crossed only one bedrock type.

Figure 5. Streams by Size Class and Gradient Class. Size 1 tributary rivers were distributed across all gradient classes while larger rivers (size 2, 3, 4) are nearly exclusively very low and low gradient systems.

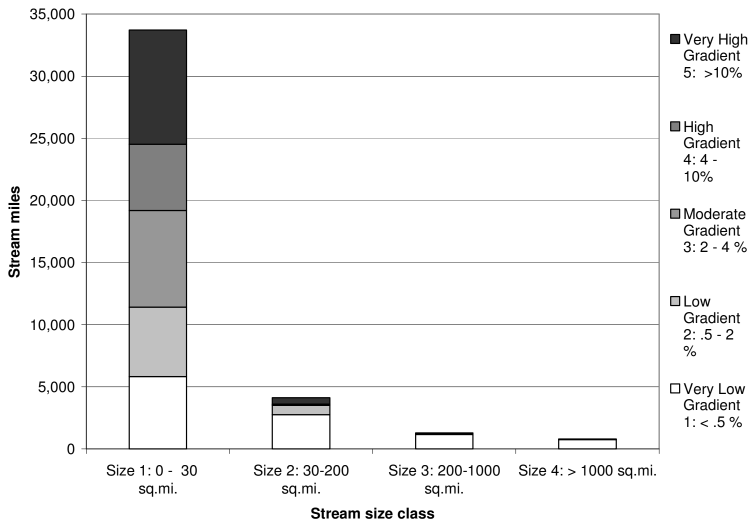
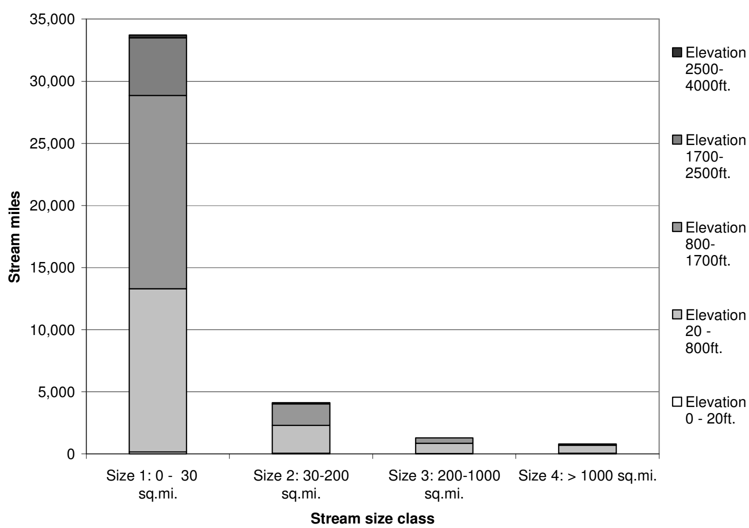


Figure 6. Streams by Size Class and Elevation Class. **S**ize 1 tributary rivers in NAP were distributed across all elevation classes, most are found at < 1700 ft. Larger rivers of size 2, 3, and 4 were found nearly exclusively at elevations < 1700ft.



5. Condition Assessment of Streams and Watersheds

Human activities have had a negative effect on the biotic integrity of aquatic systems. Intensified agriculture, road building, timber harvest, draining of wetlands, river channelization, removal of riparian vegetation, introduction of non-indigenous species and the release of harmful chemicals into aquatic environments each play a role in the compounding degradation of aquatic habitats. Their effects on streams include chemical contamination, increased sediment loads, and magnified nutrient levels while natural flow and flooding cycles have been disrupted by the construction of dams and other barriers.

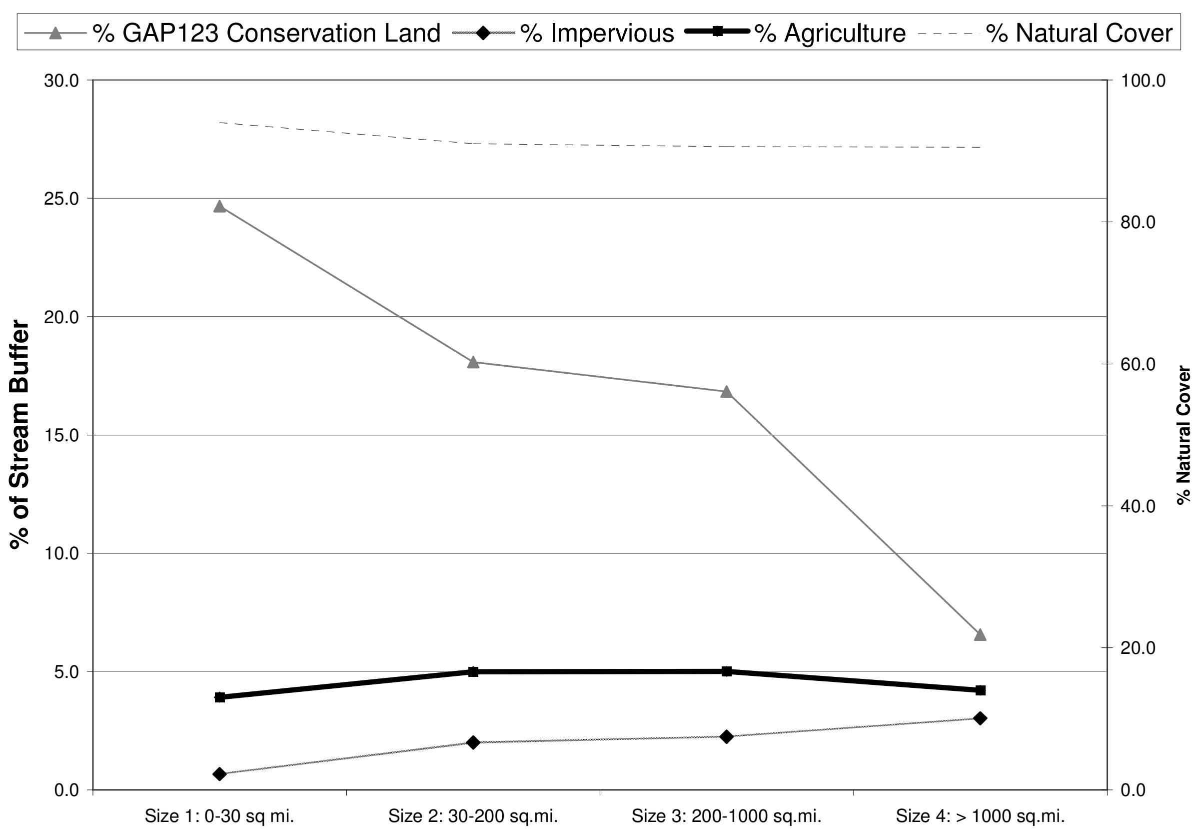
We evaluated the current condition of every stream and watershed in the US portion of the ecoregion using both an expert interview review process and a quantitative analysis of impairment (Anderson and Olivero, 2002). The latter required the compilation of spatially explicit information on roads, land cover, dams*, hydrologic alteration, point source pollution, exotics, stocking, and logging history impacts. These attributes were assembled and tabulated for a 200 meter buffer region around each stream and for its watershed (Appendix 5). Expert information and opinions on the condition of each stream was collected through a sequence of interview sessions conducted state-by-state using a standardized questionnaire. (Appendix 6).

Human land use impacts on streams in this region are small relative to other northeastern ecoregions; streams average over 90% natural cover in their buffer zones and watersheds (Table 1, Figure 7). Impacts vary with river size. Estimates of impervious surfaces increase directly with size class but based on this factor's relationship to biotic integrity, the majority of streams fall into the "no to very mildly impacted" category (CWP2003) Agricultural lands peak at 5% for mid-sized rivers while the amount of conservation land surrounding the streams decreases dramatically from 25% for small streams to 6% for large rivers (Figure 7).

Table 1. Ecoregional averages for a 200m riparian buffer area and full watersheds of size 2 streams. For dams, the stream buffer figure gives the % of watersheds for which there are no dams directly on the rivers while the watershed figure show the % of watershed that have no dams anywhere within the watershed. Dams under 6ft are excluded. .

Unit	Natural Cover	Impervious Surface	Agriculture	% Size 2 with no Dams	% Size 3 with no Dams
Stream or buffer	>90%	2.0%	4.0%	72%	33%
Watershed	90%	0.6%	6.7%	46%	14%

Figure 7. Changes in four condition variables with respect to stream size. Impervious surfaces (lowest) increases from 0.7 to 3.0 %, Agriculture, dams and landcover by stream size



Dams

Dams impair stream functions by creating barriers to upstream and downstream migration, altering in-stream temperature and water clarity, and disrupting the flood regimes necessary to maintain riparian and floodplain communities.

In the US portion of this region streams are modified by almost 1000 dams, with impairment estimates ranging from moderate to severe and becoming greater as the river size increases (Figure 8). No large rivers are completely free from dams in their watershed, but 14% have no dams on their mainstems. Among size 3 rivers 8% have no dams in their watershed and 33% have none on their mainstems. Size 2 rivers are in better condition with 39% having no dams in their watershed and 65% having none on their mainstems. Collectively headwaters are relatively unimpacted by dams with 93% having no dams in their watersheds (Figure 8)

The type and height of dams is equally important with the number of dams in evaluating the effect of dams on stream function. Large hydroelectric dams are the most common type (36%) and most of these are on our larger streams (71%). Recreational dams are the next most common (34%) and these are mostly on small size 1 streams (47% - Figure 9). To put this in context, a worldwide study of large northern rivers, rated the Hudson as moderately affected by dams while the St. John (particularly the lower section-within new Brunswick), Penobscot, Kennebec, Androscroggin, and Connecticut were rated in the lowest category of strongly affected (Dynesius and Nilsson 1993).

Figure 8 Dams By River Size 1, 2, 3, and 4 River Class

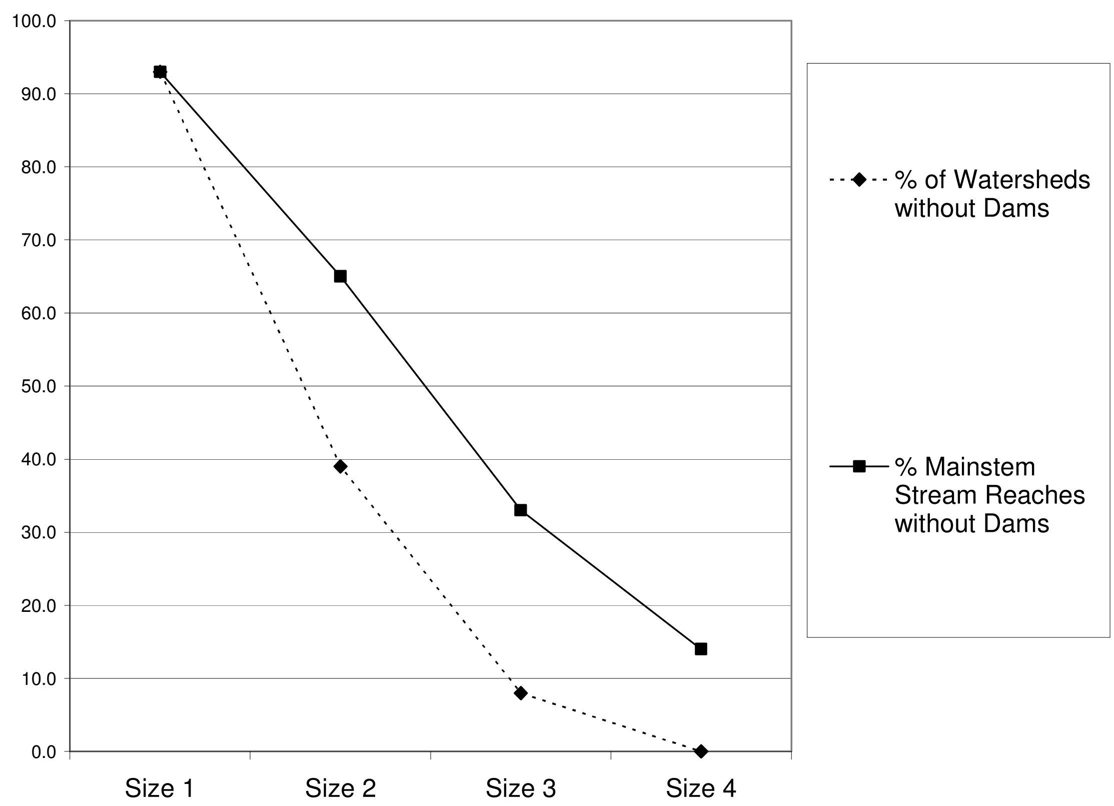
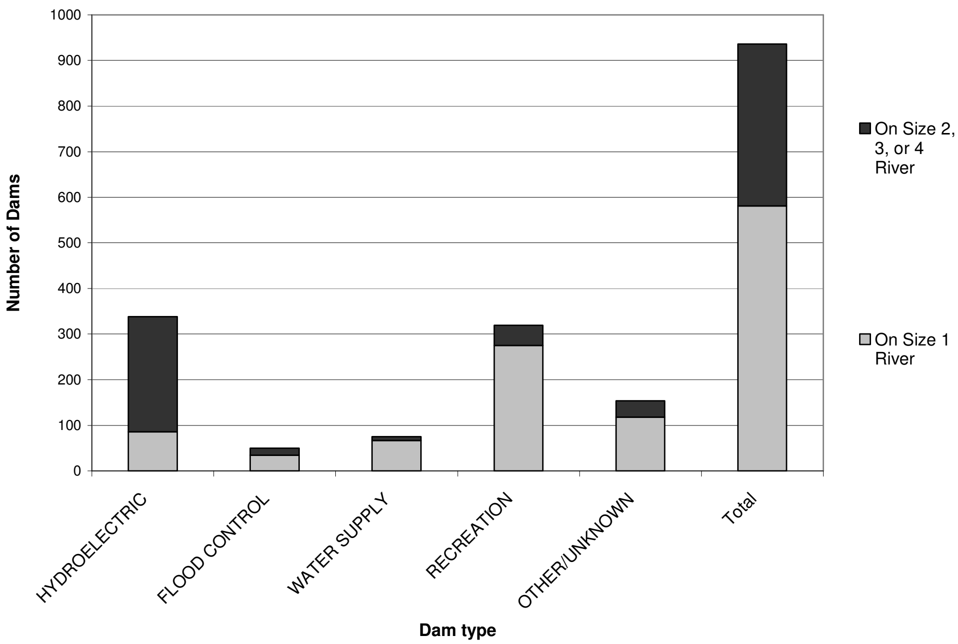


Figure 9. Number of Dams in NAP by Type and Size of River



6. Building a Portfolio of Crucial Stream Networks and Freshwater Lakes

Our objective was to identify a few high-quality examples of each stream type distributed across a spectrum of ecological settings and connected together into functional stream networks. To accomplish this we set specific objectives pertaining to:

- representation across biophysical settings
- stream quality
- connectivity to other stream reaches.

The criteria and minimum goals for each of these three dimensions are discussed below:

Representation Goals

Consider a moderate-sized stream at low elevation on calcareous bedrock contrasted with a similar stream type found at high elevations on granite. Although the two streams share common fish species they host dissimilar invertebrate and microinvertebrate communities due to differences in chemistry and temperature. Differences in the fauna may be subtle and poorly understood, or the stream biota may not be distinct enough for us to classify the two streams as separate types. To ensure that our portfolio encompassed these nuanced differences we set goals for identifying replicate samples of each stream type across a spectrum of biophysical settings (e.g. watershed groups within ecological drainage units as described previously).

Specifically, we set a minimum goal of selecting one example of each stream type within each corresponding watershed group. This guaranteed that a set of streams representing the diversity of aquatic features was identified for each watershed group. The ecoregional expert teams used their professional judgment to add additional examples to this minimum when 1) the team had finer-scale information suggesting that more examples were needed to represent the diversity within the watershed type or 2) there were equally intact interchangeable units for which the relative rank one or the other could not be decided.

An exception were the huge size 4 streams which, due to their scarcity and outstanding biotic importance, were all considered automatically a part of the portfolio with no enforced stratification. The team could choose to exclude certain sections of a given size 4 river (e.g. parts of the Androscoggin) if they were highly altered. Commonly they were included for connectivity purposes only (labeled 9c).

We set no representation goals for size 1 headwater/feeder streams. This was not due to a lack of importance of those brooks and creeks, rather, with over 100,000 examples to choose from we decided this would be more efficiently approached *after* prioritizing the larger size 2, 3, and 4 rivers. Additionally, many headwater streams were implicitly included in the portfolio because they:

1) were nested within a forest matrix site
2) are necessary for the conservation of selected larger streams
3) contain rare aquatic species targeted by the "species portfolio"

We accepted exemplary size 1 streams nominated by aquatic experts for their outstanding qualities. The result was that thousands of size 1 streams were implicitly identified by the selection process even though size 1 streams were not systematically classified and selected with representation goals in mind. We expect that any further work on the representation of size 1 streams will begin with a gap analysis of what was already captured.

Ranking and screening for quality

Within each biophysical setting, the set of available streams were ordered from best to worst using condition information and expert knowledge. Information was compiled systematically for each stream reach and consisted of the number and types of dams, the amount of developed land, agriculture and quarries, the presence of toxic release points, the density and proximity of roads and road-stream crossings. Expert knowledge was collected state-by-state through guided interviews with appropriate academics or representatives from Fish and Wildlife agencies.

We rejected streams with impervious surface estimates over 15% or with sizes less than 1 mile total, but these conditions were rarely found in the ecoregion and thus did not have a large influence on portfolio selection. More often, we encountered cases where an important stream network included a stream reach in very poor condition but that was positioned in a crucial place for maintaining connectivity. In these situations we included the reach as part of the portfolio network but labeled it with a code (9c) indicating that its role in the network was for connectivity only, not for its inherent biodiversity values.

Connectivity Goals

In riverine systems connectivity between stream reaches is of critical importance for periodic movements of stream organisms and for maintaining processes dependent on water volume and flooding. Ecoregional **design guidelines** were developed to maximize the connectivity of the stream networks selected for the portfolio. We set a minimum goal of identifying at least one connected network of streams from headwaters to coast for each size 3 watershed group and to maximize the connections between other selected stream reaches to provide movement options for potadromous fish.

To accomplish this we structured the portfolio assembly process to begin with the selection of size 3 streams. Subsequently we examined the condition characteristics of the size 2 stream options for that watershed group and, all else being equal, we prioritized streams that were connected to chosen size 3 stream. Stream networks gained prominence as more streams were selected that formed a connected system. In places where there were no viable stream options, or conversely, exemplary unconnected stream reaches, we did not force the system to comply but instead allowed for gaps in connections and for isolated, but outstanding, stream reaches to be part of the portfolio. In some cases we identified reaches that were selected solely for their connectivity value, these were specially coded (9c) to reflect this fact (Table 2). Priority networks did not necessarily have to be currently functional, as the teams sometimes identified the best potential rivers to target for restoring connectivity.

Table 2. Coding conventions for stream-reaches.

1c	Priority 1c: Best available example of a stream/river system type and part of a regional or intermediate scale connected stream network
1	Priority 1: Best available example of a stream/river system type but disjunct, not part of a focus connected stream network
9c	Necessary Connector. Considered in the portfolio only as a connector segment in a stream network. Usually found on lower mainstem reaches that are highly altered but needed for connectivity.

7. Stream Portfolio Summary

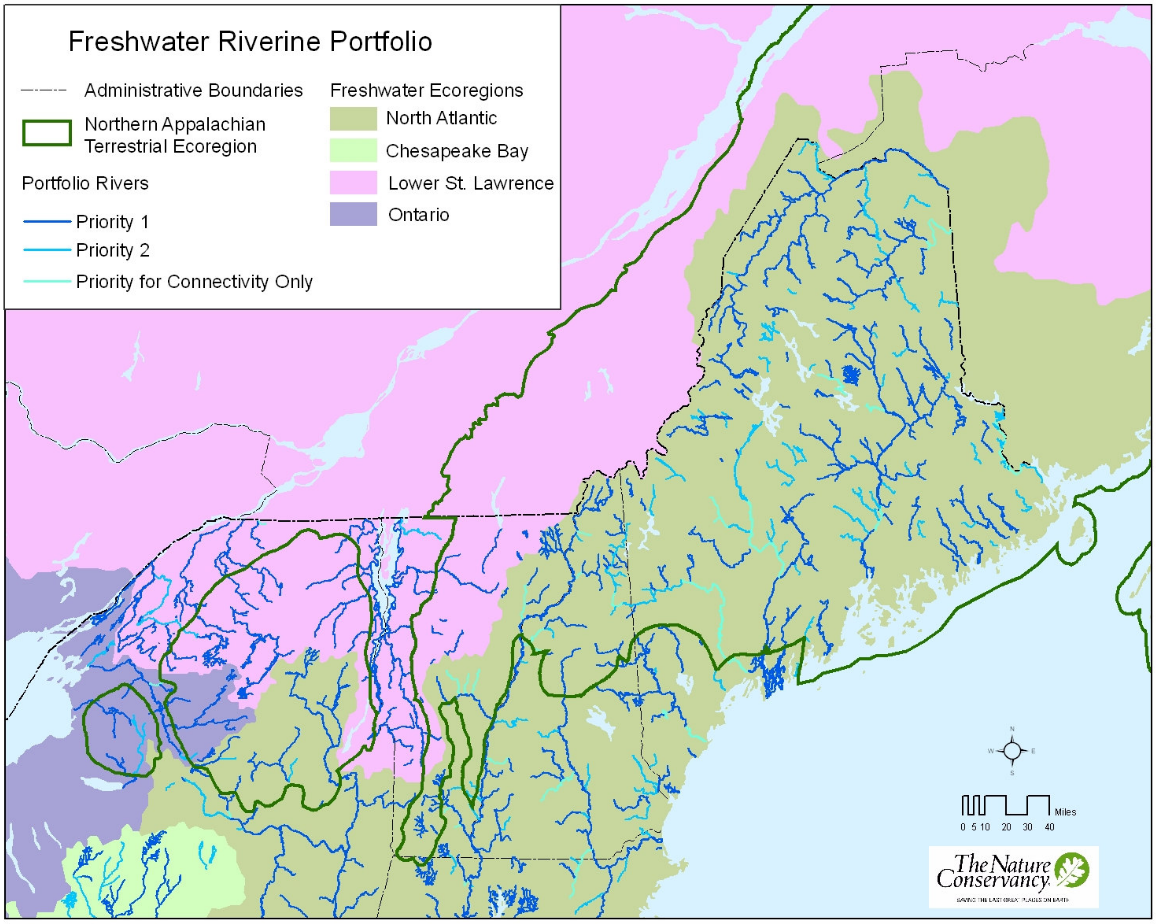
The portfolio selection process resulted in 3407 miles of high quality, mostly connected, medium to large river systems. The highest priority, Priority 1 and 1c rivers, included 3,407 miles. Additionally, 380 miles of stream reaches identified for connectivity purposes only were identified, along with 871 miles of potential alternatives to the top ranking portfolio streams (coded 2 and 2c). In all, we identified slightly more than half of the medium and large rivers in the region as necessary for conservation (size 1 rivers excluded). This ratio was somewhat higher for size 3 streams (51% of all size 2s, 68% of all size 3s and 53% of all size 4 rivers).

In aggregate, the selected portfolio rivers and their "connectivity only" reaches met our representation and connectivity goals (Table 3, Figure 10 and Appendix 5).

Table 3: Miles by River by Size, Portfolio Status, and State

River Size Class	Portfolio Priority	ME	NH	NY	VT	Total
Medium River (size 2)	1	101	0	15	17	133
	1c	1102	180	557	135	1975
	2	120	5	0	0	125
	2c	444	34	52	14	543
	9c	24	14	0	53	92
Medium River Priority 1 Total		1203	180	573	152	2108
Medium River Total		1791	232	625	219	2868
Large River (size 3)	1	38	0	0	0	38
	1c	499	52	216	70	837
	2	18	0	0	0	18
	2c	44	9	8	0	61
	9c	31	21	1	18	70
Large River Priority 1 Total		538	52	216	70	876
Large River Total		631	81	225	88	1025
Very Large River (size 4)	1c	355	40	29	0	424
	2	30	0	0	0	30
	2c	51	43	0	0	94
	9c	206	12	0	0	218
Very Large River Priority 1 Total		642	95	29	0	766
NAP Total		3064	409	879	307	4658
NAP Priority 1 Total		2095	272	818	222	3407

Figure10. Map of the Stream Portfolio for the Northern Appalachians. Portfolio (priority 1) rivers are in deep blue, alternates and "connectivity only" reaches are in lighter blue.



8. Portfolio Statistics: Current Condition and Conservation Status

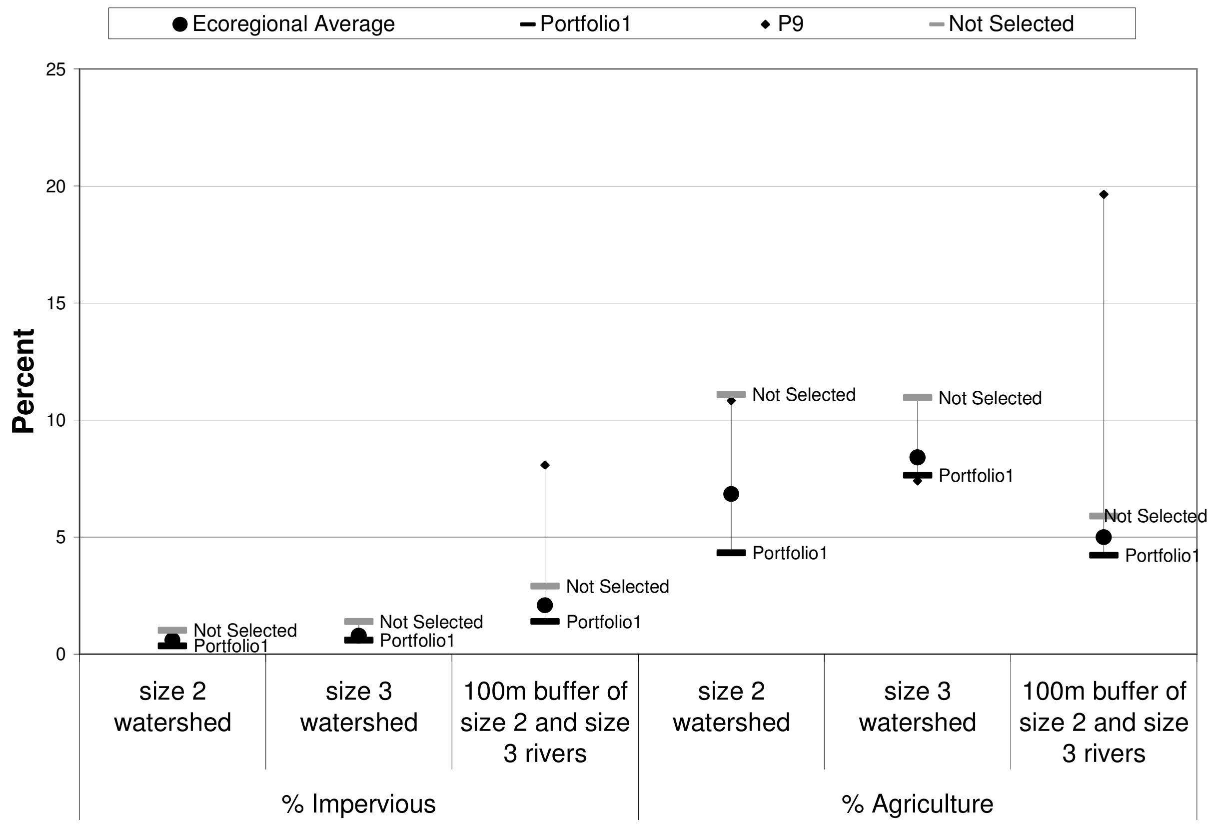
The status of portfolio rivers in terms of key measures of land use impacts, level of conservation protection, and dam impacts are presented below, contrasted against the non-portfolio rivers. Statistics are organized and reported by:

1) Watersheds of medium size rivers (size2)

2) Buffer area (100m) around all portfolio streams (excluding size 1).

We expect the portfolio streams to be in better condition over all than the ecoregional average - indeed they are (Figure 11).

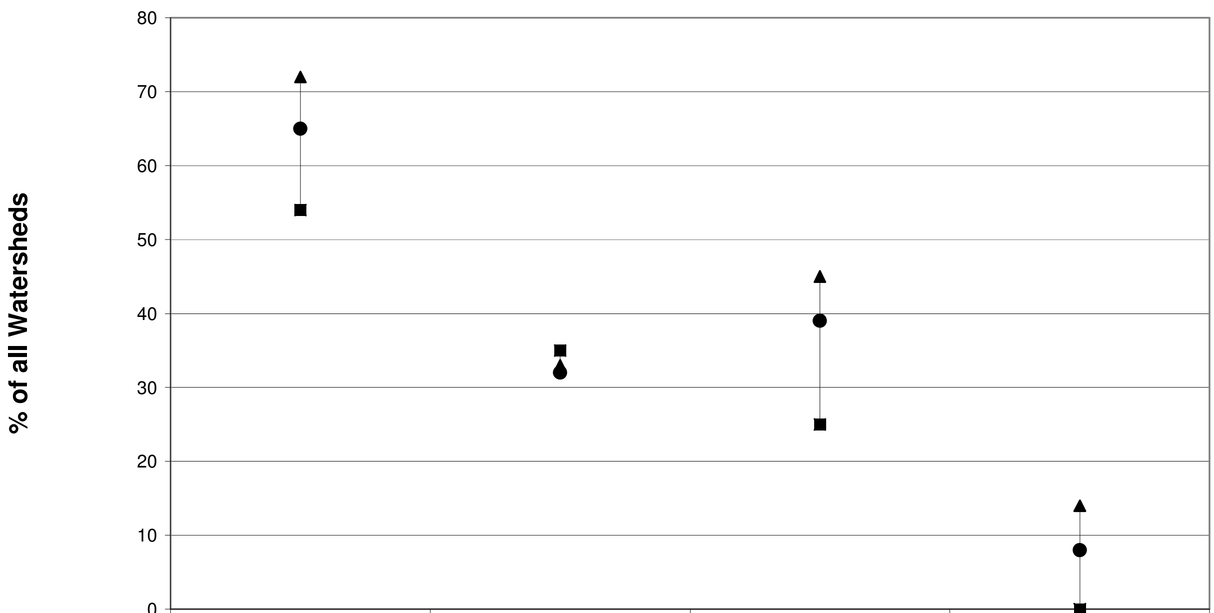
Figure 11. Impairment variables for all streams in the ecoregion. Selected portfolio streams (P1), unselected non-portfolio streams, and reaches for "connectivity only" (P9) are contrasted. For all variables, portfolio streams have a lower percentage of impervious surfaces or agriculture than non-selected streams. Percentages are given relative to watershed area or stream buffers.



On average, the selected portfolio streams contain 155 dams on their mainstems or 1 dam for every 56 stream miles - slightly better than the ecoregional average of 1 per 54 miles. Selected size 2 streams have fewer dams (1 per 62 miles) while size 3 streams have more (1 per 43 miles). Deep size 4 rivers are about equal to the average (1 per 54). The majority of dams on the portfolio streams are for hydroelectric purposes (72%). Perhaps the size 3 rivers have been the target of most dam building because of their moderate 20-40ft, widths.

The distribution of dams is not evenly distributed but tends to be concentrated on certain streams. Many portfolio streams have no dams while others have one to several. Almost three-quarters (72%) of the selected size 2 streams have no dams on their mainstems while one-third of the selected size 3 are also free from dams (Figure 12). Among those portfolio streams that *have* dam on their mainstem, they average 1 dam / 10 stream miles while the "connectivity reaches" have an average of about 3 dams per 10 stream miles.

Figure 12. Dam-free watersheds. This figure gives the percent of all watersheds in the ecoregion that are completely free of dams. The left half is based on calculations using dams found only on the stream itself. The right half is based on calculations for the whole watershed including all the size 1 headwater and feeder streams. Contrasts of the portfolio and non-portfolio streams are given against the ecoregional averages.



	% of watershed with no dams on the size 2 or 3 river		% of watershed with no dams in the watershed	
	Size 2	Size 3	Size 2	Size 3
● Ecoregion	65	32	39	8
▲ P1	72	33	45	14
■ Not selected	54	35	25	0

Connectivity to the Ocean:

Few portfolio rivers (again, the analysis was only done for the US portion) have unobstructed access to the ocean and are thus accessible to anadromous and potadromous fish (Table 4). These include the lower-most mainstems of the Androscoggin, Kennebec, and Penobscot (size 4); the Machias, East Machias, and St. George (size 3) and Pleasant, Sheepscot, Northern, Eastern, Tunk, Ducktrap, Cathance, Chandler, Dennys, Medomac, and Togus (size 2). (Although a few more portfolio rivers may actually be accessible due to fish ladders, comprehensive information on the functionality of fish ladders for our target fish was not available and dams with ladders are still considered obstructions to some fish species depending on the type of ladder and how it is maintained/run).

Table 4. Selected size 3 rivers with the least fragmentation (oc = desired ocean connectivity, Lc or c = desired local connectivity).

Major Drainage	River Name	Portfolio	No dams	No dams on size 2 or 3 mainstem	No dams on size 3 mainstem
Maine Coastal	MACHIAS R	S1oc	X	X	X
Penobscot: Mattawamkeag	MOLUNKUS STR	S1oc	X	X	X
Penobscot: Piscataquis	PLEASANT RIVER	S1oc	X	X	X
Upper St. John	ST JOHN R	S1Lc	X	X	X
Upper St. John	BIG BLACK R	S1Lc	X	X	X
Aroostook	MACHIAS R	S1Lc	X	X	X
Lower Penobscot	PASSADUMKEAG R	S1oc		X	X
Maine Coastal	E MACHIAS R	S1oc			X
St. George-Sheepscot	ST GEORGE R	S1oc			X
Meduxnekeag	MATTAWAMKEAG R, W BR	S1oc			X
Aroostook	Presque Isle Stream	S1Lc			X
Ausable	BOUQUET R	S1c			X
Oneida	FISH CR	S1c			X
White	WHITE R	S1c			X
West	WEST R	S1c			X
Salmon-Sandy	S SANDY CR	S1c, GLK portfolio			X
Salmon-Sandy	SALMON R	S1c, GLK portfolio			X
English-Salmon	SALMON R	Sxc			X
Aroostook	AROOSTOOK R, ST CROIX STR	S2Lc			X
Fish	FISH R	S2Lc			X
Lower Kennebec	CARRABASSET R	S2			X
West Branch Penobscot	CAUCOMGOMOC STR				X
Black-Ottauquechee	BLACK R				X
Meduxnekeag	MEDUXNEKEAG R				X

9. Conclusion

Our portfolio identifies the most significant and intact stream networks, representing all stream types and biophysical settings within eight major drainage basins (EDU) within the US portion of the ecoregion. The comprehensive classification and review of all size 2 and 3 watersheds and stream examples should help conservationists become more comfortable considering entire watersheds as the focus for conservation strategies rather than focusing only on aquatic species. Given the dynamic connectedness of aquatic ecosystems at multiple scales and critical terrestrial-aquatic ecosystem linkages, this approach will hopefully lead to more comprehensive, representative, and ultimately successful aquatic conservation planning.

Due to the intactness of the ecoregion, a number of alternative or interchangeable portfolio examples of certain system types were included in the data because they met our screening criteria based on review of the condition and coincident biodiversity features. Using the datasets that have resulted from this planning effort, queries can be made to highlight watersheds or stream reaches that share certain biodiversity and condition attributes such as higher % agriculture in the riparian buffer or dam impacts. In turn, this information can focus strategies around sets of watersheds and rivers sharing similar needs for restoration, increased preservation, or maintenance of current preservation efforts.

This work was completed only for the US portion of the ecoregion. Future iterations of the NAP Ecoregional plan should address the following issues which we were not able to incorporate into this iteration of the plan:

1. Inclusion of rivers and streams in Canadian portion of the ecoregion
2. Inclusion of a unified lake classification and portfolio assembly across the U.S. and Canadian sections of NAP (A lake classification and selection was completed in Maine, see appendix)
3. More data compilation and analysis of connectivity patterns, including small dams and documented fish passage structures
4. Full analysis of migratory fish targets across their range, see recommendations included in the new iteration of NAC plan
5. Integrated thresholds for metrics that can be used as surrogates of viability as more research on freshwater system viability thresholds becomes available

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