Aquatic Systems Results for Lower New England

Results for Aquatic Systems*

Classification Results

Geographic Framework for Aquatic Assessments

Zoogeographic Regions

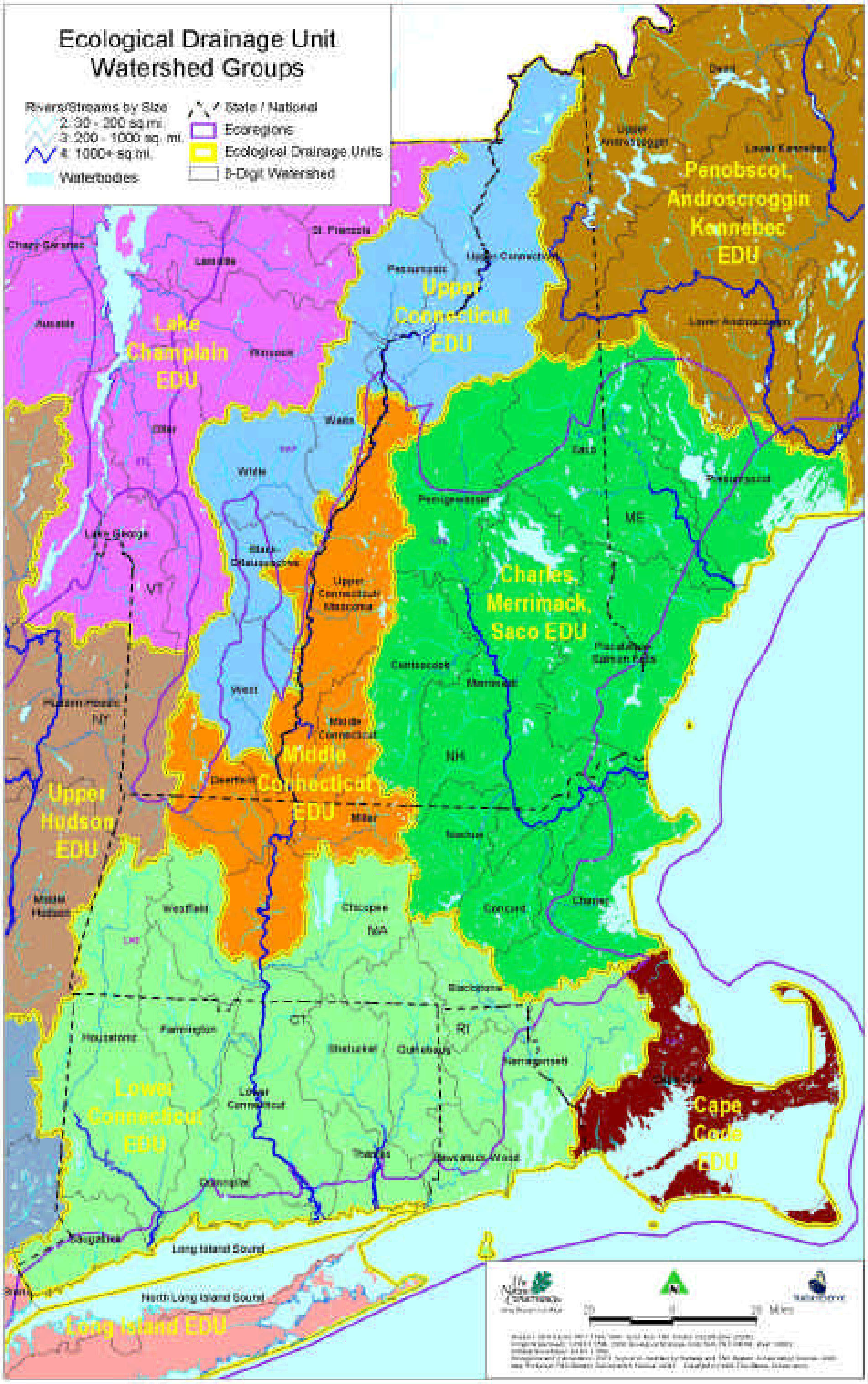
The analysis area occurred within the North Atlantic World Wildlife Fund (WWF) North American Fish Ecoregion. The North Atlantic WWF Fish Ecoregion stretches from eastern Delaware to southern Nova Scotia and covers and area of 130,000 sq.miles. The northern portion is defined by the large watersheds of the St. Croix, Penobscot, Kennebec, Merrimack, and Connecticut, while the southern portion is dominated by the Delaware and Hudson. The North Atlantic region is distinguished by runs of anadromous fish such as Atlantic salmon, shad, and herring. Atlantic sturgeon and shortnose sturgeon also occur. Most of this ecoregion has been glaciated as recently as 10,000-15,000 which has prevented the development of endemic freshwater fauna except in the very southern extent of the region which was not glaciated (Abell et al. 2000).

Ecological Drainage Units (EDUs)

The analysis region covered 5 Ecological Drainage Units (EDUs) within the North Atlantic WWF Fish Ecoregion. The 5 EDUs covered an area of 28,190 sq.mi. and included the **Upper Connecticut**, **Middle Connecticut**, **Lower Connecticut**, **Saco/Merrimack/Charles**, and **Cape Cod** Ecological Drainage Units. EDUs in New England were qualitatively delineated by the TNC Freshwater Initiative program in 1999 using USFS Fish Zoogeographic Subregions, USFS Ecoregions and Subsections, and major drainage divisions (Bryer and Smith, 2001). The EDUs were defined by grouping 8-digit US Geological Survey Hydrologic Units watersheds into units that were thought to contain aquatic systems with similar patterns of physiography, drainage density, hydrologic characteristics, connectivity, and zoogeography (Bryer and Smith 2001).

* Olivero, A.P. 2003. Results for aquatic systems. Lower New England – Northern Piedmont Ecoregional Conservation Plan; First Iteration.The Nature Conservancy, Conservation Science Support, Northeast & Caribbean Division, Boston, MA.

Figure 1: Ecological Drainage Unit Watershed Groups.



Although the five EDUs had been previously qualitatively derived by TNC Freshwater Initiative staff in 1999-2000, this analysis developed more quantitative descriptions of the physical setting and fish and mussel biota of the Ecological Drainage Units as follows:

Physical Descriptions

Table 1: Physical Descriptions of Ecological Drainage Units

EDU: Total Area and river length by river size class	Rivers	Physical Description
I. **Cape Cod** 1160 sq.mi. Rivers: Size 2 = 86 mi. Size 1 = 916 mi.	Includes Cape Cod coastal rivers directly draining to the ocean such as North, Sippican, Washpee, Quaeshunt, Slogums, West Port, along with many smaller coastal tributaries and intermittent streams.	Low elevation, very low gradient, acidic rivers primarily upon coarse grained sediments. The elevation is entirely within the 0-800ft elevation zone, with the highest elevation being 377ft. Landforms are dominated by dry flats (64%) and wet/moist flats (19%). Bedrock is primarily acidic granitic (46%) or recorded as extremely deep coarse grained sediment (47%). A small amount of acidic sed/metased and intermediate granitic/mafic bedrock exists. Surficial material is primarily coarse-grained stratified sediments (73%) or till (13%) with small amount of fine-grained sediment (6%) along the Taunton River. The EDU is 72% natural land cover with 8% in agricultural use and 21% developed.
II. **Saco – Merrimack – Charles** 9750 sq.mi. Rivers: Size 4 = 345 mi. Size 3 =695 mi. Size 2 =1603 mi. Size 1 = 12295 mi.	Very large rivers (size 4) include the Saco and Merrimack. Large inland rivers draining to the coast include the Presumpscot, Piscataqua-Salmon Falls, and Charles. Large inland rivers draining to the Merrimack include the Pemigewasset, Contoocook, Piscataquog, Suncook, Nashua, and Concord. Large tributaries of the Saco include the Ossipee and Swift. Medium sized coastal rivers draining directly to the coast include the Neponset, Charles, Saugus, Ipswich, Parker, York, Mousam, Kennebunk, Little, and Royal.	This EDU includes a diversity of aquatic habitats from northern mountainous, high elevation, high gradient systems dominated by cliffs, steep side slopes, coves and confined channels to southern, low elevation, very low gradient, meandering marshy, coastal systems. These systems cross a variety of bedrock and surficial material leading streams to have a variety of acidic to calc-neutral chemistry and flashy to stable hydrologic regimes. The elevation ranges from 0m to 6200 ft. in the White Mountains of New Hampshire. The vast majority of the EDU is within the 0-800 ft. zone (76%) and a moderate amount in the 800-1700 ft. zone (19%). Landforms are dominated by gently sloping flats (26%) and dry flats (27%), but include substantial amounts of sideslope/summit features (22%). Bedrock is primarily acidic granitic (50%) with large amounts of acidic sed/metased (24%), and small amounts of mafic/intermediate granitic (7%). A moderate amount of calcareous material is found (4% very calcareous, 15% moderately calcareous) with the calcareous material concentrated in local areas of the Nashua River and Saco River and covering nearly all the lower sections of the Presumpscot, Merrimack, and coastal rivers of the Piscataqua-Salmon Falls watershed. Surficial material is primarily till (47%), with moderate amounts of coarse-grained stratified sediments (22%) and patchy quaternary (19%), small amount of fine-grained sediment (9%). The patchy material occurs in the higher elevation mountainous areas of New Hampshire and Maine. The coarse-grained and fine-grained deposits are found primarily along the courses of the medium to larger rivers, with an additional large area of fine-grained sediment of marine clay origin near the coast in the Presumpscot, Saco, and Piscataqua-Salmon Falls Watersheds. The EDU is 81% natural land cover with 8% in agricultural use and 12% developed.
III. **Lower Connecticut** 9190 sq.mi. Rivers: Size4 = 338 mi. Size 3 = 570 mi. Size 2 = 1358 mi. Size 1 = 11546 mi.	Very large rivers (size 4) include the Housatonic, Connecticut, and Thames, with the Connecticut being by far the largest river. Large rivers draining to the coast include the Pawcatuck-Wood, Pawtuxet, Blackstone, and Taunton. Large rivers draining to the	Primarily acidic, low elevation, low to very low gradient rivers, with only a few medium gradient headwater systems. The Housatonic watershed contains substantial areas of calcareous bedrock influence. The vast majority of the EDU falls within the 0-800 ft. zone (76%) and a moderate amount in the 800-1700 ft. zone (22%). The elevation ranges from 0m to over 2605ft in the Berkshire/Taconic mountains in Massachusetts. Landforms are dominated by dry flats (39%), and gently sloping flats (25%), with some sideslopes/summits (13%). (Bedrock is primarily acidic sed/metased (48%) with significant amounts of acidic granitic (26%) and mafic/intermediate granitic (16%). A small amount of calcareous material occurs (5% very calcareous sed/metased, 5% moderately calcareous sed/metased), concentrated in the Upper Housatonic and the Shebaug. Surficial material is primarily till (71%), with a moderate amount of coarse

	Connecticut include the Farmington, Westfield, and Chicopee. Large river tributaries of the Thames include the Shetucket and Quinebaug. Medium rivers draining directly to the ocean include the Saugatuck, Mill, Hammonasset, Niantic, Palmer.	grained stratified sediment (22%), and small amount fine grained sediment (4%). The fine-grained sediment is concentrated along the direct floodplain of the mainstem Lower Connecticut. The EDU is 72% natural land cover with 12% in agricultural use and 16% developed.
IV. **Middle Connecticut** 3450 sq.mi. Rivers: Size 4 = 402 mi. Size 3 = 158 mi. Size 2 = 339 mi. Size 1 = 4359 mi.	The only very large river is the Connecticut. Large tributaries of the Connecticut include the Ashuelot, Deerfield, Millers, and Sugar.	Primarily medium elevation, medium gradient rivers headwaters draining to low elevation, low gradient systems entering the Connecticut mainstem. Predominantely acidic chemistry system except for small calcareous areas west of the Connecticut mainstem. The elevation ranges from 0m to 4728ft, with the majority of the EDU within the 800-1700 ft. zone (56%), a large amount of in the 0-800 ft. zone (32%) and a small amount in the 1700-2500 ft. zone (10%). Landforms are dominated by sideslopes/summits (44%) and gently sloping flats (22%). Bedrock is primarily acidic sed/metased (44%) with large amount of acidic granitic (26%), and small amount mafic/intermediate granitic (13%). A small amount of calcareous material is found on the western side of the Connecticut mainstem, particularly in the lower Deerfield (8% very calcareous, 7% moderately calcareous). Surficial material is primarily till (65%) with large amount of patchy quaternary (15%) and some coarse-grained stratified (13%) and fine-grained (7%). The fine-grained sediment is found primarily along the Connecticut River mainstem. The EDU is 84% natural land cover with 11% agricultural use and 5% developed.
V. **Upper Connecticut** 4640 sq.mi. Rivers: Size 4 = 140 mi. Size 3 = 228 mi. Size 2 = 537 mi. Size 1 = 3606 mi.	The only very large river is the Connecticut. Large tributaries of the Connecticut include the Ammonoosuc, Black, Ottauquechee, Passumpsic, Upper Ammonoosuc, West, and White	Medium to high elevation systems with a range of gradients but large amount of high gradient tributaries. Acidic chemistry systems are dominant east of the Connecticut mainstem, while west of the Connecticut calcareous systems dominate. The elevation ranges from 0m to 6250ft in the White Mountains of New Hampshire. The majority of the EDU is within the 800-1700 ft. zone (61%), with a large amount of in the 1700-2500 ft. zone (27%) and a small amount in the 0-800 ft. zone (6%) and 2500+ ft. zone (6%). Landforms are dominated by sideslopes/summits (70%) and gently sloping flats (17%). Bedrock is a mixture of acidic sed/metased (33%), acidic granitic (28%), very calcareous sed/metased (18%), moderately calcareous sed/metased (15%), with only a small amount of mafic/intermediate granitic (6%). The calcareous material is concentrated on the western side of the Connecticut mainstem. Surficial material is primarily till (56%) and patchy quaternary (37%), with a small amount of coarse-grained sediment (7%) and fine-grained sediment (2%). The EDU is 90% natural land with 8% in agricultural use and 1% developed.

Characteristic Fish and Mussels (from NatureServe Database, 2002)

Fish and rare mussel species distribution data by 8-digit watershed was obtained from NatureServe's Fish and G1-G3 Mussel datbase of 2002 and summarized by Ecological Drainage Unit (Table 3). A tabulation of the 61 fish species that occurred in the analysis area showed that 32 species (28 native) occurred in the Upper Connecticut EDU, 41 (36 native) occurred in the Middle Connecticut EDU, 53 (44 native) occurred in the Lower Connecticut EDU, 48 (43 native) occurred in the Saco-Merrimack-Charles EDU, and 35 (31 native) occurred in the Cape Cod EDU. Of the 3 G1-G3 Mussels for that distribution data was available, the Dwarf Wedgemussel occurred in all 5 EDUs, the Brook Floater occurred in all except the Cape Cod EDU, and the Yellow Lampmussel occurred in only the Middle Connecticut EDU.

Migratory fish were not addressed in the species analysis of the LNE Plan 2000, but a tabulation of the migratory fish species in these EDUs shows migratory fish occur in each EDU. Thus maintaining functional connected stream networks from headwaters to the ocean for migratory fish will be critical in all EDUs. The migratory fish by EDU are listed in Table 2. These fish include diadromous fish, which move between freshwater and saltwater, and potamodromous fish which move entirely within freshwater. Anadromous species spawn in freshwater and primarily grow in salt water. Catadromous species spawn in saltwater and primarily grow in freshwater. Amphidromous species may spawn and grow in either freshwater or saltwater, but have a migration to the opposite habitat for feeding and this migration is usually brief. Potamodromous fish move entirely within freshwater during their lifecycle – from as little as 1 mile to over 100 miles.

Table 2: Migratory Fish Distribution by Ecological Drainage Unit

Migratory Fish by Ecological Drainage Unit

Life History	Saco-Merrimack-Charles	Upper Connecticut	Middle Connecticut	Lower Connecticut	Cape Cod
Anadromous	Atlantic Sturgeon Blueback Herring Alewife American Shad Striped Bass Rainbow Smelt Sea Lamprey Atlantic Salmon	Rainbow Smelt Sea Lamprey Atlantic Salmon	Atlantic Sturgeon Blueback Herring Striped Bass Sea Lamprey Atlantic Salmon	Atlantic Sturgeon Blueback Herring Alewife Smerican Shad Striped Bass Rainbow Smelt Sea Lamprey Atlantic Salmon	Blueback Herring Alewife American Shad Striped Bass Rainbow Smelt Sea Lamprey
Catadromous	American Eel	American Eel	American Eel	American Eel	American Eel
Amphidromous	Shortnose Sturgeon Hickory Shad Banded Killifish Rainwater Killifish White Perch Ninespine Stickleback	Banded Killifish	Stortnose Sturgeon Banded Killifish White Perch	Shortnose Sturgeon Hickory Shad Fourspine Stickleback Sheepshead Minnow Gizzard Shad Banded Killifish White Perch Ninespine Stickleback	Shortnose Sturgeon Hickory Shad Fourspine Stickleback Gizzard Shad Banded Killifish Rainwater Killifish White Perch Ninespine Stickleback
Potamodromous	Lake Whitefish Brook Trout	Lake Whitefish Brook Trout	Lake Whitefish Brook Trout	Brook Trout	Brook Trout

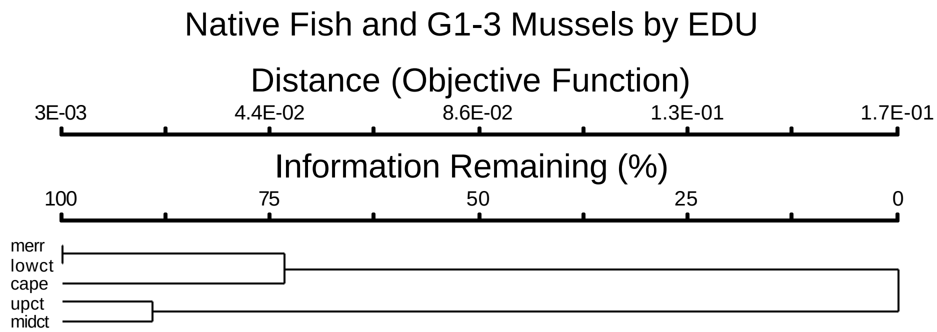
Table 3: Fish and Mussel Distribution by Ecological Drainage Unit

FISH AND G1-G3 MUSSELS by Ecological Drainage Unit

COMMON NAME	NATIVE	UP CT	MID CT	LOW CT	SACO MERR	CAPE	COMMON NAME	NATIVE	UP CT	MID CT	LOW CT	SACO MERR	CAPE
ALEWIFE	Nat.	0	0	1	1	1	LAKE TROUT	Nat./Intro.	1	1	0	1	0
AMERICAN BROOK LAMPREY	Nat.	0	0	1	1	1	LAKE WHITEFISH	Nat.	1	1	0	1	0
AMERICAN EEL	Nat.	1	1	1	1	1	LARGEMOUTH BASS	Intro.	1	1	1	1	1
AMERICAN SHAD	Nat.	0	1	1	1	1	LONGNOSE DACE	Nat.	1	1	1	1	0
ATLANTIC SALMON	Nat.	1	1	1	1	0	LONGNOSE SUCKER	Nat.	1	1	1	1	0
ATLANTIC STURGEON	Nat.	0	1	1	1	0	MUSKELLUNGE	Nat.	0	1	0	0	0
BANDED KILLIFISH	Nat.	1	1	1	1	1	NINESPINE STICKLEBACK	Nat.	0	0	1	1	1
BANDED SUNFISH	Nat.	0	1	1	1	1	NORTHERN REDBELLY DACE	Nat.	1	1	0	1	0
BLACKNOSE DACE	Nat.	1	1	1	1	0	PEARL DACE	Intro.	0	0	1	0	0
BLUEBACK HERRING	Nat.	0	1	1	1	1	PUMPKINSEED	Intro	1	1	1	1	1
BLUNTNOSE MINNOW	Intro.	0	0	1	0	0	RAINBOW SMELT	Nat./Intro.	1	0	1	1	1
BRIDLE SHINER	Nat.	0	1	1	1	1	RAINBOW TROUT	Intro.	1	1	1	1	1
BROOK TROUT	Nat.	1	1	1	1	1	RAINWATER KILLIFISH	Nat.	0	0	1	0	1
BROWN BULLHEAD	Nat.	1	1	1	1	1	REDBREAST SUNFISH	Nat.	1	1	1	1	0
BROWN TROUT	Intro	1	1	1	1	1	REDFIN OR GRASS PICKEREL	Nat.	0	1	1	1	1
BURBOT	Nat.(Intro. to Lower CT EDU)	1	1	1	1	0	ROCK BASS	Intro.	0	1	0	0	0
CHAIN PICKEREL	Nat.	1	1	1	1	1	ROUND WHITEFISH	Intro	0	0	1	0	0
COMMON SHINER	Nat.	1	1	1	1	1	SATINFIN SHINER	Nat.	0	0	1	0	0
CREEK CHUB	Nat.	1	1	1	1	0	SEA LAMPREY	Nat.	1	1	1	1	1
CREEK CHUBSUCKER	Nat.	0	1	1	1	1	SHEEPSHEAD MINNOW	Nat.	0	0	1	0	1
CUTLIPS MINNOW	Intro	0	0	1	0	0	SHORTNOSE STURGEON	Nat.	0	1	1	1	1
EASTERN SILVERY MINNOW	Nat.	1	1	0	0	0	SLIMY SCULPIN	Nat.	1	1	1	1	0
FALLFISH	Nat.	1	1	1	1	1	SPOTTAIL SHINER	Nat.	1	1	1	1	0
FATHEAD MINNOW	Intro.	0	0	0	1	0	STRIPED BASS	Nat.	0	0	1	1	1
FINESCALE DACE	Nat.	1	0	0	0	0	SWAMP DARTER	Nat.	0	0	1	1	1
FOURSPINE STICKLEBACK	Nat.	0	0	1	1	1	TESSELLATED DARTER	Nat.	1	1	1	1	1
GIZZARD SHAD	Nat./Expanding North	0	0	1	0	0	THREESPINE STICKLEBACK	Nat.	0	0	1	1	1
GOLDEN SHINER	Nat.	1	1	1	1	1	TROUT-PERCH	Intro.	0	0	1	0	0
HICKORY SHAD	Nat.	0	0	1	1	1	WHITE PERCH	Nat.	0	1	1	1	1
LAKE CHUB	Nat.	1	1	1	1	0	WHITE SUCKER	Nat.	1	1	1	1	1
							YELLOW PERCH	Nat.	1	1	1	1	1

Review of the fish distribution information shows that certain species are widespread throughout the analysis area. Native fish occurring in all of the 33 watersheds in the analysis area include white sucker, golden shiner, brown bullhead, yellow perch, brook trout, and chain pickerel. Fish occurring in all EDUs and 28-32 of the 33 watersheds include common shiner, longnose dace, tessellated darter, banded killifish, redbreast sunfish, American eel, blacknose dace, and fallfish. These fish are associated with the widespread and common aquatic habitats of the region and appear to tolerate the ranges of climate and stream temperature that normally occurs across the region. Although all these fish occur throughout the analysis area, some species such as white suckers, yellow perch, golden shines, and common shiners appear to be aquatic habitat generalists. They use a wide range of local habitats from creeks to small and medium rivers to large lakes and have ranges that extend significantly outside the region (Page and Burr 2001). Other species such as brown bullhead, brook trout, dace, fallfish, and tessellated darter prefer specific habitats that although specific, are widespread throughout the analysis region. For example, Brown bullheads need the deep water of large lakes and rivers, that occur in every EDU (Williams 2002). Brook trout need cool, oxygen-rich creeks to medium rivers that are also common habitats throughout the region. Blacknose dace, fallfish, and longnose dace prefer faster current streams with gravel to rocky substrate. Blacknose and longnose dace prefer springs and cool, clear creeks with moderate to swift currents over gravel or rocks, with longnose dace preferring slightly faster currents. Fallfish avoid small streams but prefer gravel, rubble bottomed pools and runs of small to medium rivers and lake margins. Certain widely distributed fish in this region such as banded killifish and tessellated darter prefer slower current waters that are also commonly found in this region. American eels are fish with a unique catadromous life history that are widely distributed throughout the region. Non-native fish that occur in the region included the bluntnose minnow, brown trout, cutlips minnow, fathead minnow, largemouth bass, pearl dace, pumpkinseed, rainbow trout, rock bass, round-whitefish, and trout-perch. Lake trout, rainbow smelt, and burbot were native in some of the watersheds and non-native in others.

The increased numbers of species present in the Lower Connecticut EDU and Saco-Merrimack-Charles EDU in comparison to the Middle Connecticut, Upper Connecticut, and Cape EDU likely represents the increased diversity of aquatic habitat niches within these EDUs, particularly their direct connection with the ocean. The Lower Connecticut and Saco-Merrimack-Charles EDU have both diverse upland areas of habitat as well as significant sections of large, medium, and small coastal rivers where estuarine habitat is abundant and where there are access points for anadromous and catadromous species. The Cape Cod EDU has direct connection with the ocean and estuarine habitat; however, the sizes of rivers in the Cape Cod EDU are quite small; there are no size 3 rivers and only 5 examples of size 2 rivers. The Cape Cod EDU is also quite uniform in its physical habitat diversity that may also limit the number of species that can find adequate habitat in this EDU. The dominance of higher gradient stream systems, higher elevations and colder temperatures, and the lack of estuarine habitat limits the aquatic habitat niches available in the Middle and Upper Connecticut EDUs. Certain species likely experience physiological limits to the colder climate in these EDUs which may explain the lower number of species in these EDUs.



A Sorensen Similarity Distance Index analysis using all native fish and G1-G3 mussel distribution (current and historical presence/absence) showed the distribution of species within the Saco-Merrrimack-Charles EDU and Lower Connecticut EDU are extremely similar. The Lower Connecticut EDU and Saco-Merrimack-Charles EDU shared 40 of 47 species. The only differences was that satinfin shiner, gizzard shad, rainwater killifish, sheepshead minnow did not occur in the Saco-Merrimack-Charles and lake trout, lake whitefish, and northern redbelly dace did not occur in the Lower Connecticut. The satinfin shiner, rainwater killifish, sheepshead minnow, and gizzard shad appear to be at the northeastern limit of its range. The satinfin shiner occurs in only the Saugatuck watershed within the Lower Connecticut EDU, but its distribution extends extensively south to North Carolina. The sheepshead minnow, rainwater killifish, and gizzard shad occur in coastal estuarine areas from Cape Cod to Texas but do not appear to have been able to colonize north of the Cape (Williams 2002). Lake trout and lake whitefish are likely absent from the Lower Connecticut EDU as they prefer cold deep lakes and cold large rivers that are lacking in the Lower Connecticut EDU. Northern redbelly dace prefer colder boggy water and sluggish mud bottom creeks and boggy ponds that are also absent in the Lower Connecticut EDU.

The next most similar EDU to the Lower Connecticut and Saco-Merrimack-Charles is the Cape Cod EDU. These three EDUs share 29 of the total 53 fish species . All fish in the Cape Cod EDU also occured in the Lower Connecticut EDU, and 27 of the 29 Cape fish also occurred in the Saco-Merrimack-Charles EDU (Sheepshead minnow and rainwater killifish were missing from the Saco-Merrimack-Charles, per above distribution limit discussion.) The fish fauna of the Cape thus appears to be a subset of the fauna of the Lower Connecticut and Saco-Merrimack-Charles edu. Native Fish that occurred in all EDUs except for the Cape Cod EDU included lake trout, spottail shiner, lake chub, longnose sucker, atlantic salmon, slimy sculpin, creek chub, longnose dace, redbreast sunfish, and blacknose dace. As mentioned previously, the Cape Cod EDU lacks any rivers greater than size 2 and has quite uniform low gradient physical habitat throughout and this limited physical habitat diversity likely limits the number of species that can find adequate habitat in this EDU.

The Upper Connecticut EDU and Middle Connecticut EDU show greater divergence from the Cape, Lower Connecticut, and Saco-Merrimack-Charles EDUs. The Upper Connecticut and Middle Connecticut EDUs share 26 species of their 38 total species. One species, eastern silvery minnow, occurred in both the Middle Connecticut and Upper Connecticut but was missing from the Lower Connecticut, Cape, and Saco-Merrimack-Charles. Eight fish species (alewife, American brook lamprey, fourspine stickleback, hickory shad, ninespine stickleback, striped bass, swamp darter, and threespine stickleback) occurred in the Lower Connecticut, Cape, and Saco-Merrimack-Charles but did not occur in either the Upper or Middle Connecticut EDU.

Many of these were anadromous (alewife, hickory shad) that only migrate a short distance inland to spawn and thus do not get up into the Middle and Upper Connecticut. Other appear to be fish adapted to the estuarine environment such as striped bass and threespine stickleback. Fourspine stickleback, ninespine stickleback, three spine stickleback, and swamp darter appears to occupy low gradient coastal rivers from Connecticut to Louisiana and although they are not strictly estuarine, they do not appear to occupy rivers more than 100 miles from a coast. Fish that occurred in all EDUs except for the Upper Connecticut EDU include shortnose sturgeon, blueback herring, banded sunfish, American shad, white perch, redfin or grass pickerel, creek chubsucker, and bridle shiner. Again, many of these fish are migratory fish that migrate from coastal rivers to spawn and use habitat within the Middle Connecticut but do not migrate further up into the Upper Connecticut (shortnose sturgeon, blueback herring, American shad). The finescale dace only occurred in the Upper Connecticut EDU, and similar to the northern redbelly dace, it prefers cold boggy creeks and lakes that are more common in the more northern watersheds. No fish occurred in all EDUs except for the Middle Connecticut EDU. The NatureServe database did show muskellunge and rock bass only occurring in the Middle Connecticut EDU, but this may be an error in the database as other fish distribution references show muskellunge also in Vermont and rock bass not in New England, but in New York. Trout-perch, bluntnose minnow, gizzard shad, and pearl dace occurred only in the Lower Connecticut EDU. The geographic range of trout-perch, bluntnose minnow, and gizzard lies primarily west of New England. No fish species occurred in all 3 Connecticut EDUs and not in the Cape Cod and Saco-Merrimack-Charles EDU.

Watershed Classification: Aquatic Ecological Systems

The watershed classification resulted in following multiple scale watershed Aquatic Ecological System types distributed as follows:

Table 4: Watershed Aquatic Ecological System Groups by Size and Ecological Drainage Unit

Number of System Types by EDU and Size	Saco-Merrimack-Charles EDU	Upper CT EDU	Middle CT EDU	Lower CT EDU	Cape EDU	Total Number of types
Size 3: large rivers (200-1000 sq.mi.)	7	5	3	6	0	19
Size 2: medium rivers (30-200 sq.mi.)	7	5	5	8	1	24
Size 1: headwaters to small rivers (0-30 sq.mi.)	9	12	3	14	0	38
Note total # of Size 3 types does not equal sum of the individual EDU counts because type 17 and type 15 occur in both Upper CT and Middle CT						
Note total # of Size 2 types does not equal sum of the individual EDU counts because type 5 and 17 occur in both Upper CT and Middle CT						

Figure 2: Size 2 Watershed Systems

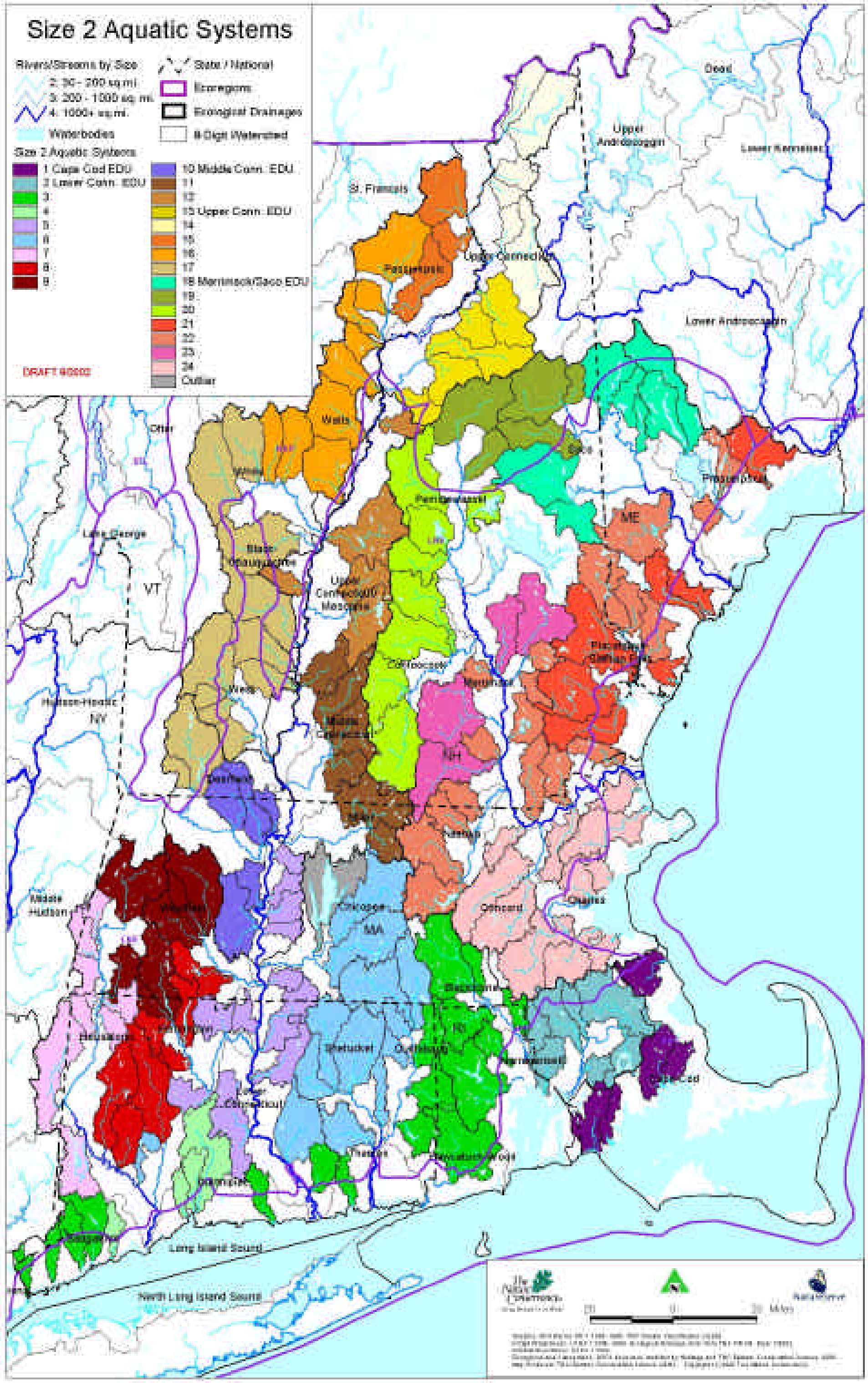
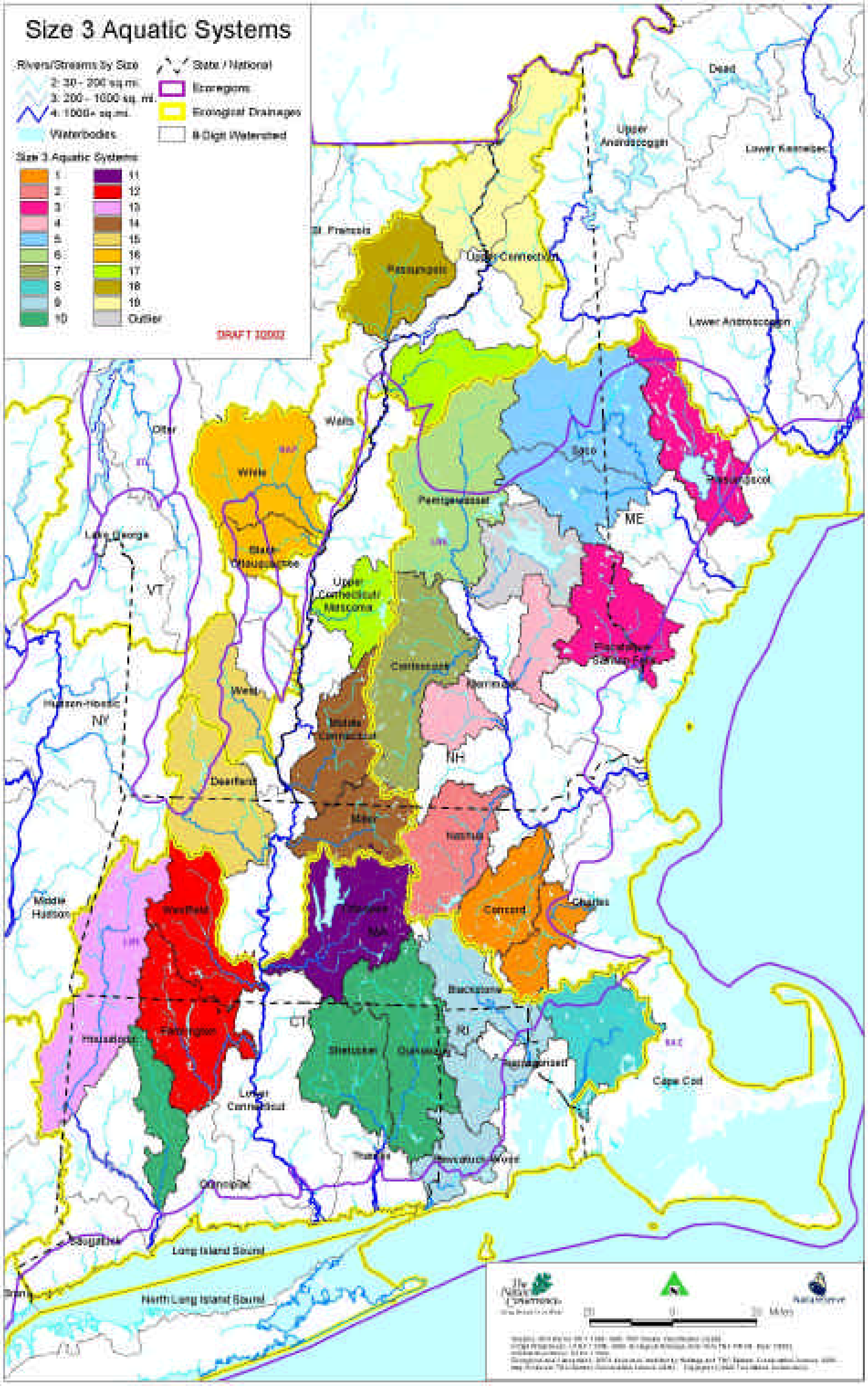


Figure 3: Size 3 Watershed Systems



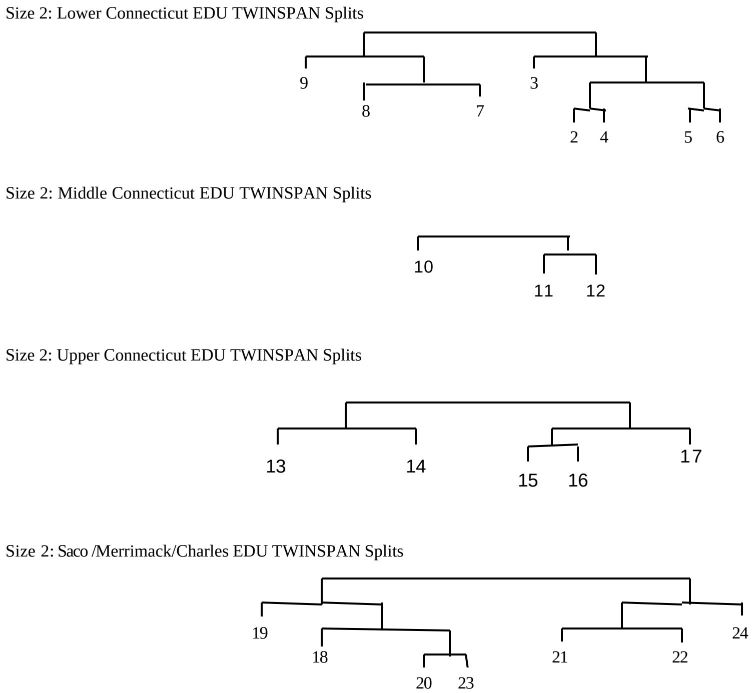
TWINSPAN Relationships

The hierarchical relationships among the system are shown in Figures 4 and 5. Number on these hierarchical flow figures represent the system types. Two-Way Indicator Species Analysis (TWINSPAN) statistical cluster analysis was performed using watersheds as classification units and ELUs as species to derive these hierarchical relationships. TWINSPAN analyses were run with pseudospecies cuts of 0, 2%, 5% 10% 20%, 40%, 60%, and 80%. TWINSPAN is a multivariate classification method based on correspondence analysis designed for sample unit x species data (Hill 1979). TWINSPAN is a top-down classification technique that repeatedly divides a correspondence analysis ordination space using an underlying gradient at each cut. At each successive cut, the previous groups are bifurcated into two more additional groups.

The output TWINSPAN clusters formed the basis of the watershed classification major systems. Although many of the 2nd level cluster splits were used as systems, in some cases 3rd and even 4th level clusters were used where they were deemed to have ecological significance. The TWINSPAN groupings for size 3 and size 2 systems were extensively reviewed by Arlene Olivero and Mark Anderson. Manual review was necessary to determine ecologically significant clusters because certain groups contain much more diversity than others and it was determined that in these cases a lower level of clustering should be used to obtain a cluster group with more homogenous members. In certain cases, certain watersheds were also removed or added to major system groups for spatial cohesiveness, connectivity issues, and other spatial issues TWINSPAN does not incorporate. For example, in some coastal areas of the analysis, we felt the connectivity to the coast should have been weighted heavier in the classification so we combined and broke a few TWINSPAN clusters accordingly. In the TWINSPAN analysis it was also not possible to more heavily weight certain “species” other than with the percentage values, so additional ecological weighting of certain features such as coastal estuarine habitat had to be added manually. Size 1 systems have not undergone a thorough manual review and are based on the raw TWINSPAN output. The systems were reviewed by experts during the expert meetings and although no system type was eliminated, in three cases the experts recommended moving a particular watershed into a neighboring system group.

Elevation explained the first splits, with bedrock and landform driving further splits. Analysis was performed separately for each EDU for size 2 systems due to the large number of watershed examples in each EDU. Analysis was performed for all five EDUs together for the size 3 systems due to the smaller number of watershed examples. See the specific discussion below for further information on which physical characters drove the system splits.

Figure 4: Size 2 Watershed System TWINSPAN Splits



Explanation of Size 2 Watershed TWINSPAN System Splits

Lower Connecticut

7-9 split from 2-6 because 7-9 where primarily moderate elevation and 2-6 were low elevation. 9 split from 7-8 because 9 was not heavily calcareous or moderately calcareous. 7 split from 8 because 7 was highly calcareous and 8 was only moderately calcareous. 3 split from 2,4,5,6 because 2 was primarily acidic granitic and 2,4,5,6 were primarily acidic sedimentary. 2,4 split from 5,6 because 5,6 included some moderate elevation and had more gentle slopes. 2 split from 4 because all of 4's members were coastal connected and had more fine grained flats. 2 drained to Rhode Island bay and had more coarse sediment and wet flats. 5 split from 6 as 5 included short rivers that connected to the Connecticut River mainstem where the valley was dominated by broad areas of flat fine grained sediment flats near the Connecticut mainstem.

Middle Connecticut

10 split from 11 and 12 because elevation was lower in 10 and 10 had a swath of moderately calcareous bedrock along the western side of the Connecticut River as the valley begins to rise. All of 10 had some calcareous tributaries and some had calcareous mainstem systems. 10 has large areas of fine grained flats near the Connecticut River mainstem, with the 2 more northern Deerfield watershed drainage examples in more mountainous setting and a potential subgroup within system 10. Both 11 and 12 are acidic and very similar in landform, however 12 is dominated by acidic granitic bedrock and 11 is primarily acidic sedimentary.

Upper Connecticut

13 and 14 split from 15-17 primarily due to elevation as 13,14 have significant amounts of high and some very high elevation areas. 13 split from 14 because 13 is primarily acidic granitic and 14 is acidic sedimentary. Both are similar in landform. 15 and 16 split from 17 because 15 and 16 have calcareous or moderately calcareous bedrock and 17 is primarily acidic sedimentary. 15 split from 16 as 16 is more strongly calcareous and 16 has more steep slopes.

Saco/Merrimack/Charles

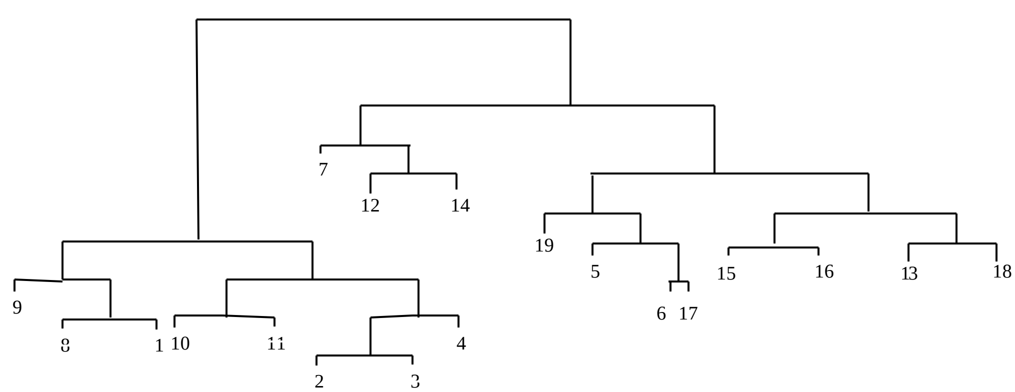
18,19,20,23 split from 21,22,24 because 21,22,24 were coastal low elevation systems while 18, 19, 20, 23 had some moderate to high elevation areas and were inland. 19 split from 18, 20, 23 as 19 was the only system primarily in the high elevation zone, with even some areas of very high elevation. 18 split from 20 and 23 as 18 was more dominantly acidic granitic and drain directly to east coast Maine while 20 and 23 are more mixed acidic granitic and acidic sedimentary and drain to the Merrimack River. 20 split from 23 due to 23 being more southerly and including more low elevation and gentle slopes. 24 split from 21 and 22 as 24 was extremely flat while 21 and 23 were hilly. 21 split from 22 as 21 was flatter and flowed directly into the ocean or estuary bays without going through a size 3 river.

Cape Cod

There were only 5 size 2 examples in the Cape Cod EDU. They were all so similar in physical setting, the decision was made not to split them into further system classes.

Figure 5: Size 3 System TWINSPAN Splits

Size 3 Watershed TWINSPAN Splits



Explanation of Size 3 Watershed System TWINSPAN Splits

9,8,1,10,11,2,3,4 split from 7,12,14,19,5,6,17,15,16,13,18 due to elevation with 9,8,1,10,11,2,3,4 all being in the low elevation while 7,12,14,19,5,6,17,15,16,13,18 were all primarily within the moderate to high elevation zone. Within 9,8,1,10,11,2,3,4 group, 9,8,1 split from 10,11,2,3,4 because 9,8,1 were all entirely extremely low in elevation and dominated by flats while 10,11,2,3,4 were dominated by gentle slopes and although they were low in elevation they did included some areas of moderate elevation. 9 split from 8,1 because 9 had less coarse sediment flats and less wetflats and more gentle slopes, although all three had a large amount of coarse sediment flats and wet flats. 9 also had a greater proportion of acidic granitic bedrock. 8 split from 1 because 8 had more fine grained sediment and less till, more acidic sedimentary bedrock, much fewer gentle slopes, and more moist wet/flats. 10,11 split from 2,3,4 primarily because of differences in landform and drainage position; both had the same elevation and mixture of bedrocks. 10,11 drained to Long Island Sound directly or through the Connecticut River and had more dry flats on till and more wetflats. 2,3,4 drained directly to the Atlantic coast and had more summits, upper slopes, sideslopes, and slope bottoms. 10 split from 11 as 10 was coastal, more predominantly in low elevation and had more acidic granitic bedrock. 11 drained to the Connecticut mainstem and had more had more mafic intermediate granitic bedrock, more coarse sediment, and more wet/moist flats. Although 2,3 and 4 all had predominantly acidic granitic bedrock, 2,3 split from 4 because 2,3 also had substantial amounts of calcareous and moderately calcareous bedrock while 4 had no moderately calcareous or calcareous bedrock. 2 split from 3 as 3 was lower in elevation and had more moderately calcareous and less calcareous bedrock and less coarse sediment.

Within 7,12,14,19,5,6,17,15,16,13,18 group, 7,12,14 split from 19, 5, 6, 17,15,16,13,18 as 7,12,14 had a larger percentage of area in the low elevation and were dominated by gentle slopes with substantial flats and little sideslopes and coves. 7 split from 12, 14 as 7 had some areas in higher elevation zones, more acidic granitic, and more sideslopes/coves. 12 split from 14 as 14 had more patchy surficial, less flats, and although both 12 and 14 had small areas of locally moderately calcareous bedrock, 12.had larger amounts of these small areas. 19, 5, 6, 17 split from 15,16,13,18 because 15,16,13,18 all had substantial large areas of moderately calcareous or calcareous bedrock. 15, 16 split from 13, 18 again primarily because of the influence of calcareous bedrock and its associated features, with 13 and 18 having more calcareous/moderately calcareous bedrock than 15, 16. 18 split from 13 as 18 had a much higher percentage of calcareous/moderately calcareous bedrock (80%) than 13 (44%). 18 also had more summits, steep slopes, sideslopes and coves. 15 split from 16 because 15 had more higher elevation areas and more acidic granitic bedrock while 16 had more moderately calcareous/calcareous bedrock and much more summits, steep slopes, and sideslopes.

Summary System Physical Descriptions

The systems were characterized by different landscape characteristics in elevation , geology, gradient, landform, and connectivity. See LNEsize2.xls and LNEsize3.xls for a more detailed description of the physical setting of each watershed system. A short textual summary of the physical characteristics of each watershed system type is provided in Tables 5 and 6.

Table 5: Size 2 Watershed System Summary Descriptions

Size 2 Systems	Connectivity to Size 3 System or direct to ocean	Physical Descriptions
1	ocean	Low elevation, very low gradient rivers on glacial outwash till and coarse sandy sediment over acidic granitic bedrock, significant portion of watershed may be tidal and brackish; numerous wetlands; chemistry acidic
2	8(9), some ocean	Low elevation watershed dominated by flats; low to very low gradient trunks and tribs; on thin till and acidic metasedimentary bedrock, some coarse sediment outwash; numerous wetlands; chemistry acidic
3	9,10, some ocean	Low elevation watershed dominated by flats and gentle slopes; low gradient rivers meandering over gentle slopes on till, acidic to intermediate granitic bedrock; chemistry acidic; some brackish
4	ocean	Low elevation watershed dominated by flats and gentle slopes; low gradient rivers meandering over gentle slopes on till, acidic sedimentary bedrock; chemistry acidic; brackish
5	12	Low elevation watershed dominated by gentle slopes and flats;low gradient river system in central valley on till and coarse grained sediments over acidic sedimentary bedrock; small rivers joining directly to CT mainstem; large areas of fine grained sediment in valley along CT mainstem; chemistry acidic
6	10,11	Low elevation watershed dominated by gentle slopes and flats;low gradient river systems with some moderate gradient tributaries as the elevation rises on valley margins; till over acidic sedimentary to granitic metamorphic bedrock w/ some intermediate granitic;
7	13	Moderate to low elevation watershed dominated by gentle slopes with some sideslopes/coves along with flats; low gradient trunks with moderate to high gradient tributaries in the "marble valley"; till over calcareous bedrock; chemistry calcareous-neutral
8	12	Moderate to low elevation watershed dominated by gentle slopes along with large areas of flats and some sideslopes/coves; low gradient trunks and more moderate gradient trunks along sideslopes and coves; till on acidic sedimentary and moderately calcareous bedrock; chemistry: calc/neutral
9	12,13	Moderate elevation river systems over mainly gentle slopes with some area of sideslopes and coves along with pervasive flats; low to moderate gradient trunks with moderate to very high gradient tribs; till over acidic sed/metased and granitic bedrock; chemistry acidic
10	15	Low to moderate elevation watershed dominated by sideslopes and coves with some gentle slopes and steep slopes; low to moderate gradient river trunks with moderate to high gradient tributaries; till over on acidic sedimentary bedrock with large areas of locally calcareous to moderately calcareous sediments;
11	14	Moderate to low elevation watershed dominated by gentle slopes with substantial sideslopes and coves; acidic sedimentary/metasedimentary and acidic granitic till. Moderate gradient trunks with moderate to high gradient tribs
12	17	Moderate to high elevation watershed dominated by sideslopes and coves with substantial steep slopes and gentle hills; high gradient headwaters flowing into lower gradient trunks; primarily acidic granitic, acidic sedimentary/ metasedimentary, and some mafic/intermediate granitic till.
13	17	Moderate to high or very high watershed dominated by sideslopes with substantial areas of steep slopes and gentle hills; high gradient headwaters flowing into lower gradient trunks; primarily acidic granitic till (with some areas of mafic/intermediate granitic till).
14	19	High elevation watershed dominated by sideslopes; acidic sedimentary/ metasedimentary till. Swath of mafic-intermediate granitic till across CT Lakes, with scattered wet/moist flats.

15	18	Moderate to high elevation with large amount of cliff/steep slope/upper slope/summit/sideslope features; primarily acidic granitic with some acidic sedimentary, also high percentage of moderately calcareous bedrock; mainly till
16	16,18	Primarily moderate elevation, some high elevation; very large amount of summits, upper slopes, sideslopes; over 90% calcareous with 60% strongly calcareous and 30% moderately calcareous; mainly till
17	15,16	Moderate to high elevation with some very high elevation; very large amount of cliff/steep slope/summit/upper slope/sideslopes; Primarily acidic sedimentary with also large areas of acidic granitic; primarily patchy with also large amount of till;
18	5	Low to moderate elevation watershed dominated with sideslopes, coves/steep slopes/summits concentrated at Ossippee Mtns. Widespread flats and gentle slopes with acidic granitic till. Dry flat-coarse grained sediments occur in relatively large patches, particularly around Ossippee Lake.
19	5,6	High elevation mountainous watershed; dominated by coves/steep slopes/cliffs/summits. Scattered areas of acidic granitic and acidic sedimentary/metasedimentary till.
20	6,7	Moderate elevation watershed dominated by mountainous terrain esp. in Pemigewasset, with acidic granitic till. Isolated patches of acidic sedimentary/ metasedimentary and moderately calcareous till interspersed with wet/moist flats. Terrain less mountainous in Contoocook.
21	ocean	Low elevation and low relief dominated by flats and gentle hills; primarily acidic granitic with acidic sedimentary, but also large percentage of moderately calcareous (38%); till with large amount of coarse and fine sediment
22	2,3	Low elevation watersheds with widespread flats and gentle slopes with acidic granitic and acidic sedimentary/ metasedimentary till, interspersed with dry flats with coarse-grained sediments. Low gradient trunks with moderate gradient tribs
23	4	Low elevation watershed dominated by gentle slopes with acidic granitic and sedimentary/metasedimentary till. Isolated, very small patches of moderately calcareous till and dry flats with coarse grained sediments (more common near mainstem of the Merrimack).
24	1, some ocean	Low elevation watershed with low gradient rivers and streams on mostly acidic igneous and metamorphic bedrock(locally calcareous), some tidal in lower reaches

Table 6: Size 3 Watershed System Summary Descriptions

Size 3 Systems	Physical Description
1	Low elevation watersheds dominated by gentle slopes and flats; on primarily acidic granitic bedrock with surficial till and some coarse sediment
2	Low elevation watersheds dominated by gentle slopes and flats; on primarily acidic granitic with large areas of acidic sedimentary, moderately calcareous and calcareous bedrock; surficial till and some coarse sediment
3	Low elevation watersheds dominated by gentle slopes and flats; on primarily acidic granitic bedrock with surficial till and some coarse and fine sediment
4	Low elevation watersheds dominated by gentle slopes with substantial areas of sideslopes;on a mixture of acidic sedimentary and acidic granitic bedrock with surficial till and some areas of patchy and coarse sediment.
5	Low elevation watersheds dominated by sideslopes with substantial amounts of steep slopes and gentle slopes; on primarily acidic granitic bedrock with primarily patchy surficial
6	Moderate to low elevation watersheds dominated by sideslopes and steep slopes; on acidic granitic and acidic sedimentary bedrock with patchy surficial.
7	Moderate to low elevation watersheds dominated by sideslopes and gentle slopes; on acidic granitic and acidic sedimentary bedrock with till surficial.
8	Low elevation watersheds dominated by dry flats, wet flats, and coarse sediment flats; on acidic sedimentary and acidic granitic bedrock with surficial primarily coarse sediment with some areas of till
9	Low elevation watersheds dominated by flats; on acidic granitic and acidic sedimentary bedrock with surficial till with some coarse sediment
10	Low elevation watersheds dominated by gentle slopes and flats; on primarily acidic sedimentary bedrock with surficial till
11	Low and moderate elevation watersheds dominated by gentle slopes and flats; on primarily acidic sedimentary bedrock with surficial till
12	Moderate to low elevation watersheds dominated by gentle slopes with substantial areas of flats and sideslopes; with acidic sedimentary bedrock with surficial till
13	Moderate to low elevation watersheds dominated by sideslopes; on primarily calcareous bedrock with surficial till
14	Moderate to low elevation watersheds dominated by gentle slopes; on primarily acidic sedimentary bedrock on surficial till
15	Moderate to high elevation watersheds dominated by sideslopes with substantial gentle slopes and sideslopes; on acidic sedimentary bedrock with surficial till and patchy quarternary sediment
16	Moderate to high elevation watersheds dominated by sideslopes with substantial steep slopes; on acidic sedimentary, calcareous, and moderately calcareous bedrock with surficial till and patchy quarternary sediment
17	Moderate to high elevation watersheds dominated by sideslopes with gentle slopes and steep slopes; on primarily acidic granitic bedrock with surficial till
18	Moderate to high elevation watersheds dominated by sideslopes and gentle slopes; on calcareous and moderately calcareous bedrock with surficial till
19	Moderate to high elevation watersheds dominated by sideslopes and gentle slopes; on acidic sedimentary and acidic granitic bedrock with surficial till; some areas of locally moderately calcareous bedrock

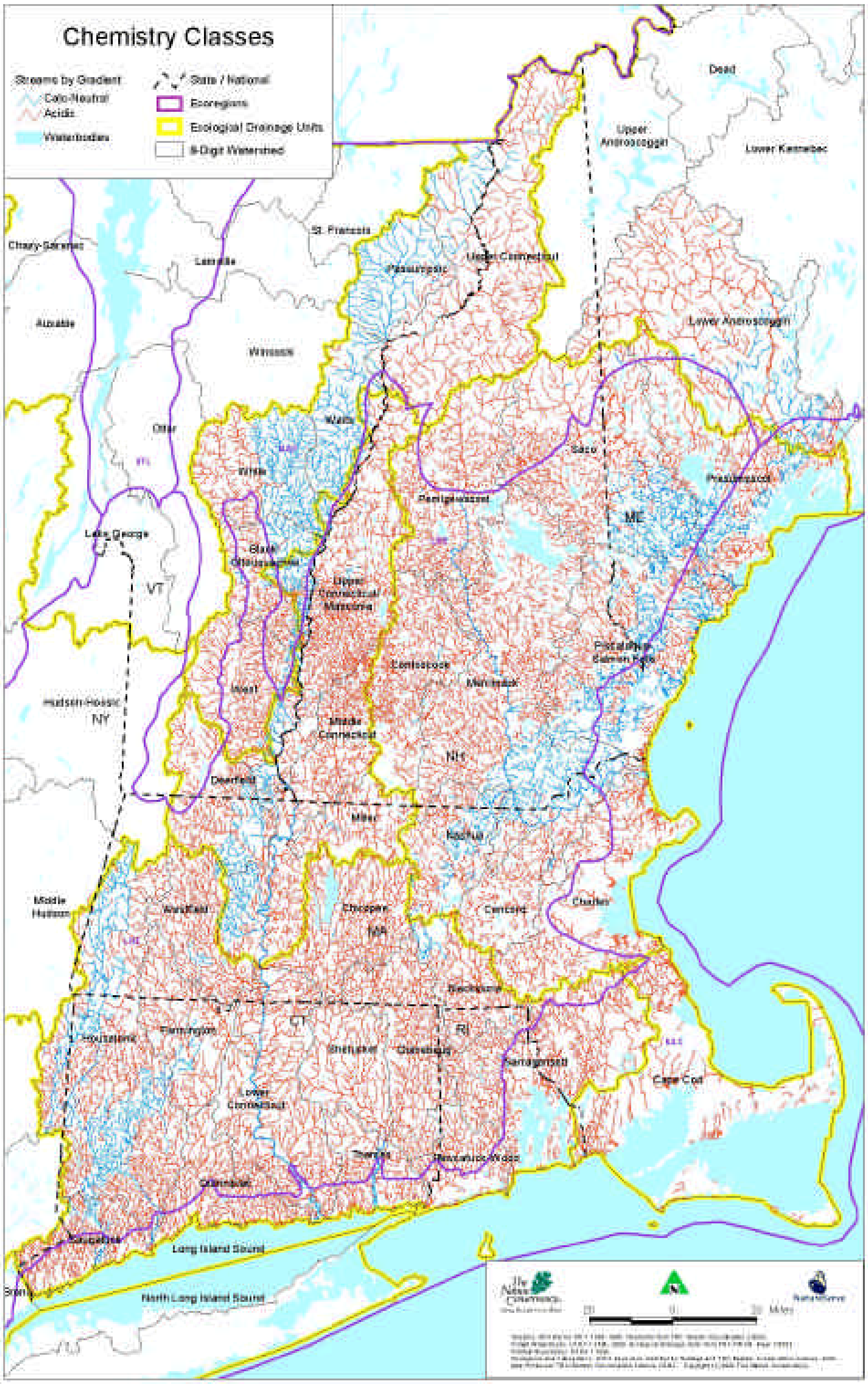
Reach Level Classification: Macrohabitats

The reach level macrohabitat analysis had 480 possible unique combinations based on unique combinations of their size class (4 classes) x elevation class (4 classes) x gradient classes (5 classes) x chemistry classes (2 classes) and connectivity classes (3 classes). Distributions of individual attributes such as size, gradient, or chemistry can be reviewed by studying the following figures:

Figure 6: Reach Size Classes

Figure 7: Reach Gradient Classes

Figure 8: Reach Simplified Chemistry Classes



Of these 480 possible combinations, 143 unique combinations occurred in the analysis area. The most common types and most rare types of size 1, 2, and 3 reaches are listed in the tables below. The patterns of common and rare types reflect the overall distribution of aquatic habitats in the region as low elevation, low gradient acidic streams predominate and calcareous and higher elevation streams are less common. For example, 4 of the 5 most common size 1 types were acidic reaches in low elevation, with low, very low, or moderate gradient. One of the 5 most common size 1 types was a moderate elevation, high gradient, acidic stream type. Four of the 5 most common size 2 types were in low elevation with low or very low gradient. 3 of these 4 were acidic. One of the 5 most common size 2 types was in moderate elevation, with low gradient and an acidic chemistry. All of the most common size 3 types were in low elevation with low, very low, or moderate gradient. 4 of these 5 had acidic chemistry. The least common types were dominated by calcareous, high gradient, and high elevation types.

Table 7: Most Common Size 1-3 Reach Macrohabitat Types

MACRO	# EDUS	# Reaches	Description
11211	5	3600	size1, low elevation, low gradient, acid, stream connected
11111	5	2548	size1, low elevation, very low gradient, acid, stream connected
11311	5	1740	size1, low elevation, moderate gradient, acid, stream connected
12411	4	1572	size1, moderate elevation, high gradient, acid, stream connected
11212	5	1311	size1, low elevation, low gradient, acid, lake connected
21111	5	883	size2, low elevation, very low gradient, acid, stream connected
21211	5	472	size2, low elevation, low gradient, acidic stream connected
21121	4	201	size2, low elevation, very low gradient, calc-neutral, stream connected
21112	5	177	size2, low elevation, very low gradient acid, lake connected
22211	4	134	size2, moderate elevation, low gradient, acid, stream connected
31111	4	588	size3, low elevation, very low gradient, acid, stream connected
31211	4	256	size3, low elevation, low gradient, acid, stream connected
31121	3	105	size3, low elevation, very low gradient, calc-neutral, stream connected
31311	4	56	size3, low elevation, moderate gradient, acid, stream connected
31112	4	32	size3, low elevation, very low gradient, acid, lake connected

Table 8: Least Common Size 1-3 Reach Macrohabitat Types

MACRO	# EDUS	# Reaches	Description
12522	2	2	size1, moderate elevation, very high gradient, calcareous, lake connected
11423	1	1	size1, low elevation, high gradient calcareous, ocean connected
13221	1	1	size1, high elevation, low gradient, calcareous, stream connected
14412	1	1	size1, very high elevation, high gradient, acid, lake connected
14521	1	1	size1, very high elevation, very high gradient, calcareous, stream connected
22122	1	1	size2, moderate elevation, very low gradient, calc-neutral, lake connected
22321	1	1	size2, moderate gradient, moderate gradient, calc-neutral, stream connected
23111	1	1	size2, high elevation, very low gradient, acid, stream connected
23212	1	1	size2, high elevation, low gradient, acid, lake connected
23311	1	1	size2, high elevation, moderate gradient, acid, stream connected
31123	1	1	size3, low elevation, very low gradient, calc-neutral, stream ocean connected
31213	1	1	size3, low elevation, low gradient, acid, ocean connected
31412	1	1	size3, low elevation, high gradient, acid, lake connected
31422	1	1	size3, low elevation, high gradient, calc-neutral, lake connected
31512	1	1	size3, low elevation, very high gradient, acid, lake connected

Classification: Discussion and Conclusion

Freshwater ecological systems are highly dynamic and diverse ecosystems that exist along a continuum, from headwaters to large river mouths. Within these ecosystems, abiotic and biotic interactions occur at multiple spatial and temporal scales to influence the form, function, and patterns of aquatic biodiversity. To identify the different types of aquatic ecosystems in Lower New England, this assessment implemented a multiple scale physical classification based on the principles of evaluating nested watersheds at multiple scales within a regional climate and biogeographic framework (Maxwell 1995, Frissell 1986, Higgens et al. 1998).

The classification provides an apriori hypotheses regarding how large-scale suites of environmental features directly or indirectly influence aquatic biota. When watersheds of similar size occur under similar climatic and zoogeographic conditions and share a similar set of physical features such as elevation zones, geology, landforms, gradients and drainage patterns, they may be reasonably expected to contain similar aquatic biodiversity patterns (Tonn 1990, Jackson and Harvey 1989, Hudson et al. 1992, Maxwell et al. 1995, Angermeier and Winston 1998, Pflieger 1989, Burnett et al. 1998, Van Sickle and Hughes 2000, Oswood et al 2000, Waite et al. 2000, Sandin and Johnson 2000, Rabeni and Doisy 2000, Marchant et al 2000, Feminella 2000, Gerritsen et al 2000, Hawkins and Vinson 2000, Johnson 2000, Pan et al 2000). The physical landscape classification variables in this analysis were chosen because they 1) displayed low spatial and temporal variation at the given watershed scale under consideration and 2) have been shown to strongly affect the form, function, and evolution of aquatic ecosystems and ecological processes at the considered scales (Frisell 1986).

Classification watershed scale variables included watershed size, elevation, bedrock, surficial geology, and landform. Stream watershed area was used as a proxy for stream size. Watershed area is correlated with local scale measures of stream width, depth, flow velocity and also influences flow rate, velocity, regime, and channel morphology. Elevation was used to represent local climate variation which limits some aquatic species distributions, influences forest type and organic input to rivers, stream temperature, and flow regime due to differences in snow melt and precipitation. Bedrock and surficial geology were used due to their control of water chemistry, stability of flow, and sedimentation which influence the hydrologic character and habitat of streams. For example sediment texture and cohesion impacts the stability of flow as sediments with higher porosity (coarse grained sandy surficial sediments, acidic sedimentary/metasedimentary bedrocks, calcareous bedrocks) are likely to have more stable groundwater dominated flows as precipitation in these landscapes is more likely to percolate into the groundwater than to runoff overland into streams. Less porous sediments (fine grained clay surficial, acidic granitic bedrock, other crystalline bedrocks) are likely to have more flashy hydrologic regimes as surface water flows predominate unless the watersheds contain sufficient multiple fracture/fault zones for groundwater recharge. Gradient and landform were used because they influence stream morphology (confined/meandering), flow velocity, substrate composition, and habitat types due to differences in soil type, flow velocity, moisture, nutrients, and disturbance history. For example, the morphology of valley floors differs substantially between mountains and lowland areas due to contrast in the degree of landform controls on stream meandering. Likewise, lower gradient streams in New England typically have sand, silt and clay substrates while high gradient streams typically have cobble, boulder, and rock substrates (Argent et al 2002).

The classification used WWF Fish Zoogeographic Ecoregions and Ecological Drainage Units to place the physical watershed and reach classification within the context of its regional geoclimate and zoogeographic setting. Large-scale geologic and climate factors constrain the development of both physical habitat and biological structure of smaller spatial scales through their large-scale controls on temperature, chemistry, hydrology, stream morphology, nutrient and sediment delivery, and on patterns of disturbance (flood, fires, hurricanes, major geologic events) that operate over this scale (Frisell 1986, Poff and Allan 1995, Hawkins et al. 2000). Geoclimate settings also influence zoogeographic distributions of aquatic biota as the current and historical pattern of linked aquatic networks has influenced isolation, dispersion, and speciation. Analysis of the physical characteristics and fish and mussel distributions between Ecological Drainage

Units supported the distinctiveness between these units. Although the fauna of the Cape Cod EDU appeared very similar to the fauna of the Lower Connecticut EDU, its physical and climatic setting provides a unique physical setting in which these species are adapted to live. Analysis of the fauna of the EDUs also highlighted the presence of migratory fish within each of the EDUs, including species such as atlantic sturgeon, blueback herring, alewife, american shad, rainbow smelt, sea lamprey, atlantic salmon, shortnose sturgeon, hickory shad, banded killifish, and brook trout. These migratory fish and connected networks of aquatic systems will be conservation targets within each EDU.

The classification shows a wide diversity of aquatic ecosystem types occur in the region. These systems can be hierarchically classified into a smaller number of "most similar "groups at successively larger spatial scales. The classification can be used to highlight patterns in regional diversity and spatially reference all examples of the distinctive classification unit types. Complex relationships of how elevation, geology, and landform interact to dominate physical patterns within watersheds can be teased apart by studying the classification break points. For example, elevational differences followed by variation in bedrock geology dominated upper levels of the watershed classification break points, with finer breaks primarily due to finer differences in landform and both bedrock and surficial geology.

Simple queries can be performed to highlight watershed systems with a similar ecological signature. For example watersheds with large areas of highly calcareous bedrock (size 2: 7, 8, 10, 15, 16, 22; size 3: 15, 16, 13, 18,3, 12) or watershed of low elevation with high amounts of coarse grained sediments (size 2: 1, 2, 3, 4; 24, 22,21 size 3: 8, 2, 3). Watershed system groups with similar physical signatures, but in different Ecological Drainage Units can be highlighted such as size 2 system 24 and 3 that are both low elevation flat watersheds with some gentle hills on primarily on acidic granitic bedrock with surficial till and large areas of coarse sediment deposits. The difference is that system 3 is in the Lower Connecticut EDU draining into Long Island Sound or Narraganset Bay, while system 24 is in the Saco, Merrimack, Charles EDU and drains into Boston Harbor or the northshore of the Atlantic. Other examples include size 2 systems 19 and 13 that are both high elevation to very high elevation mountainous watersheds dominated by sideslopes/coves and steep slopes on primarily acidic granitic with large amounts of patchy and till surficial. System 19 is in the Saco, Merrimack, Charles EDU and system 13 is in the Upper Connecticut EDU. Likewise, size 2 system type 11 and 20 are very similar as they are both moderate to low elevation watersheds dominated by sideslopes and gentle hills on primarily acidic granitic bedrock with till surficial. System 20 is in the Saco, Merrimack, Charles EDU while system 11 is in the Middle Connecticut EDU. Similar patterns can be found in the size 3 systems between systems 6 (Upper Connecticut) and 17 (the Saco, Merrimack, Charles EDU) and between 8 (Saco, Merrimack, Charles EDU) and 9 (Lower Connecticut EDU). Finer scale patterns in environmental diversity within the watersheds can also be identified by studying the reach classification and Ecological Land Unit distribution within the watersheds.

Although this analysis did not explore the correlation of the watershed or reach level classification to specific aquatic species assemblages, assemblage differences (and/or population genetic differences) are currently expected or expected to develop over evolutionary time between the different types given their different environmental settings. Future studies will be necessary to investigate the level of association between species assemblages and this classification; however, certain generalized relationships can be postulated. For example, for proposed associations between aquatic biota and the reach level classification in the Upper

Connecticut and Middle Connecticut Ecological Drainage Units see the Appendix of the Aquatic Methods section.

Condition Results

GIS Screening

Size 2 Watershed: Within System Relative Analysis

A "Within System" Analysis was run to highlight the highest ranked watershed within each system type. A subset of the related condition variables were used in a Principle Components Analysis (PCA) Ordination within each of 3 relatively non-correlated impact categories. PCA Ordination runs were made separately within each EDU for the Land Cover/Road Impact and for the Dam/Drinking Water Supply Impact. The 1st output axis, which explained most of the variance of watersheds in terms of that impact area, was used to create a single reduced "rank variable" to rank the watersheds from best to worst in terms of that impact area. Simple ranking, instead of ordination, was ultimately used to create a summary rank for the Point Source Impact because all the input point source response variables were extremely highly correlated with the variable *total point sources / stream mile*.

The input variable set for PCA Ordination/Ranking Analysis was as follows:

Land Cover/Road Impact Ordination Variables:

- P_imp - % impervious surfaces
- P_nat - % nat land cover
- Rdx_pstmi - # road stream crossings per stream mile
- Rdtot_psqmi - total miles of roads per square miles of the watershed

Dam / Hydrologic Alteration Impact Ordination Variables:

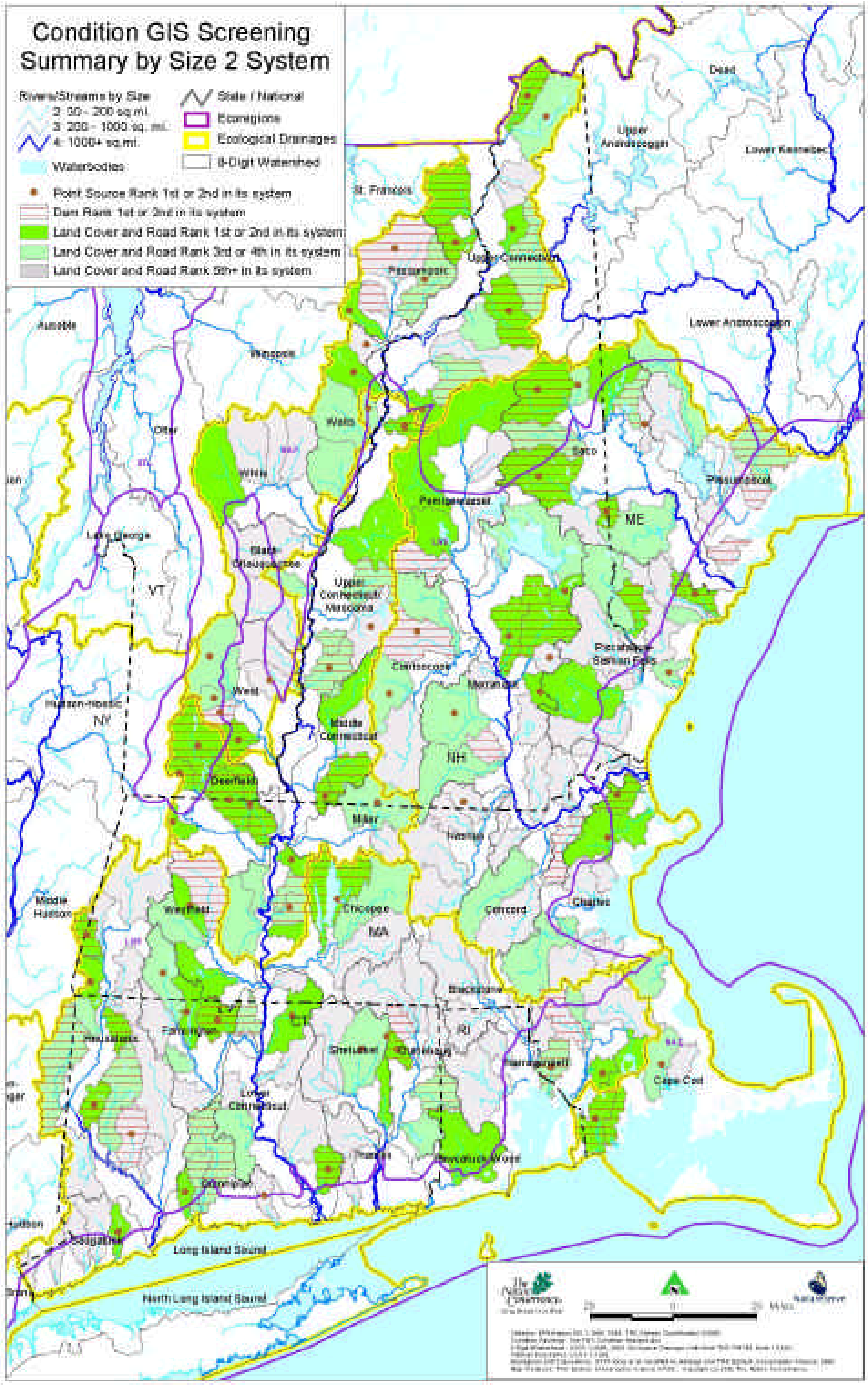
- Damst_stmi - total NID dams per stream mile
- Ldam_stmi - # large dams ([Nid_height] >= 20 or storage > 1000 if NID height was less than 20 feet)
- Tsto_pstmi = total storage in acre/feet per stream mile
- Dwspmi - # drinking water supply per stream mile

Point Source Impact (simple ranking):

- TPS_pstmi - total point sources per stream mile (CERCLIS, IFD, PCS, TRI, MINES)

Figure 9 displays the size 2 watersheds that ranked high within their system type. This map highlighted watersheds that had scored 1st –4th within the system type in terms of land cover/road impacts as a solid, those that had scored 1st or 2nd in dam/drinking water supply impacts as a hatch, and those that had scored 1st in point source impacts as a dot.

Figure 9: Size 2 Watershed Relative Ranking Summary Map



Size 2 Watershed: Landscape Context Non-Relative Ranking

A "Non-System Relative" analysis was run to investigate the range of Landscape Context of size 2 watersheds in the entire analysis area (Figure 10). By measuring the watersheds on a single "ruler" or scale across the entire analysis area, it provided a template to compare size 2 watershed examples across different system types. A simplified set of condition variables were used to explore the range in quality within the analysis area. Percent developed land cover, percent agriculture land cover, total road density per watershed area were chosen because these variables were considered to summarize distinct and important classes of impacts to aquatic systems.

The following class breaks were used to integrate the input variables into an overall Landscape Context rank of watersheds into classes 1-5 (Table 9). These categories were developed in consultation with Mark Anderson after review of the population distribution for each variable. The lowest class of the percent developed category, greater than 15%, is well supported in the literature as a threshold beyond that streams show clear signs of degradation and fair to poor Indices of Biotic Integrity (IBIs) (Jones and Clark 1987, Steedman 1988, Couch et al. 1997, Dreher 1997, Wang et al. 1997, Yoder et al. 1999, Gordon and Majumder 2000, Schueler 1994). This category was choosen to stand alone as a "maximum threshold category"/ unique rank 5 category due to its known biological relevance. The remaining percent developed distribution was broken into 4 categories. A narrow very good (1) class to represent the best 10% of watersheds, followed by a rank 2 and 3 class that each represented 25% of the watersheds, and a category 4 that represented 20% of the watersheds. For the percent agriculture and road density variables, no thresholds have been uniformly identified in the literature (Fitzhugh 2000). For these variables, 4 categories were used due to the imprecision of identifying a biologically significant category 5 or maximum threshold category. The following class breaks were made by examining the range and distribution of data. A narrow best (1) category was used to represent the top 10% of watersheds, followed by another rather narrow rank 2 category representing about 20% of the watersheds, a rank 3 category representing 35% of the watersheds, and a category 4 representing 35-40% of the watersheds (similar to combining the categories 4 and 5 from the percent developed rank that also held 40% of the watersheds together). The overall Landscape Context watershed rank was determined by worst individual category score.

Table 9: Size 2 Watershed Landscape Context Ranking Criteria

Landscape Context Rankings			
Rank	%Developed	% Agriculture	Road Density (mi rd/sq.mi. watershed)
1	<1%	<3%	<1
2	1-2%	3-6%	1-2.5
3	2-6%	6-10%	2.5-3.5
4	6-15%	>10%	>3.5
5	>15%		

Figure 10: Size 2 Watershed Non-Relative Ranking Summary

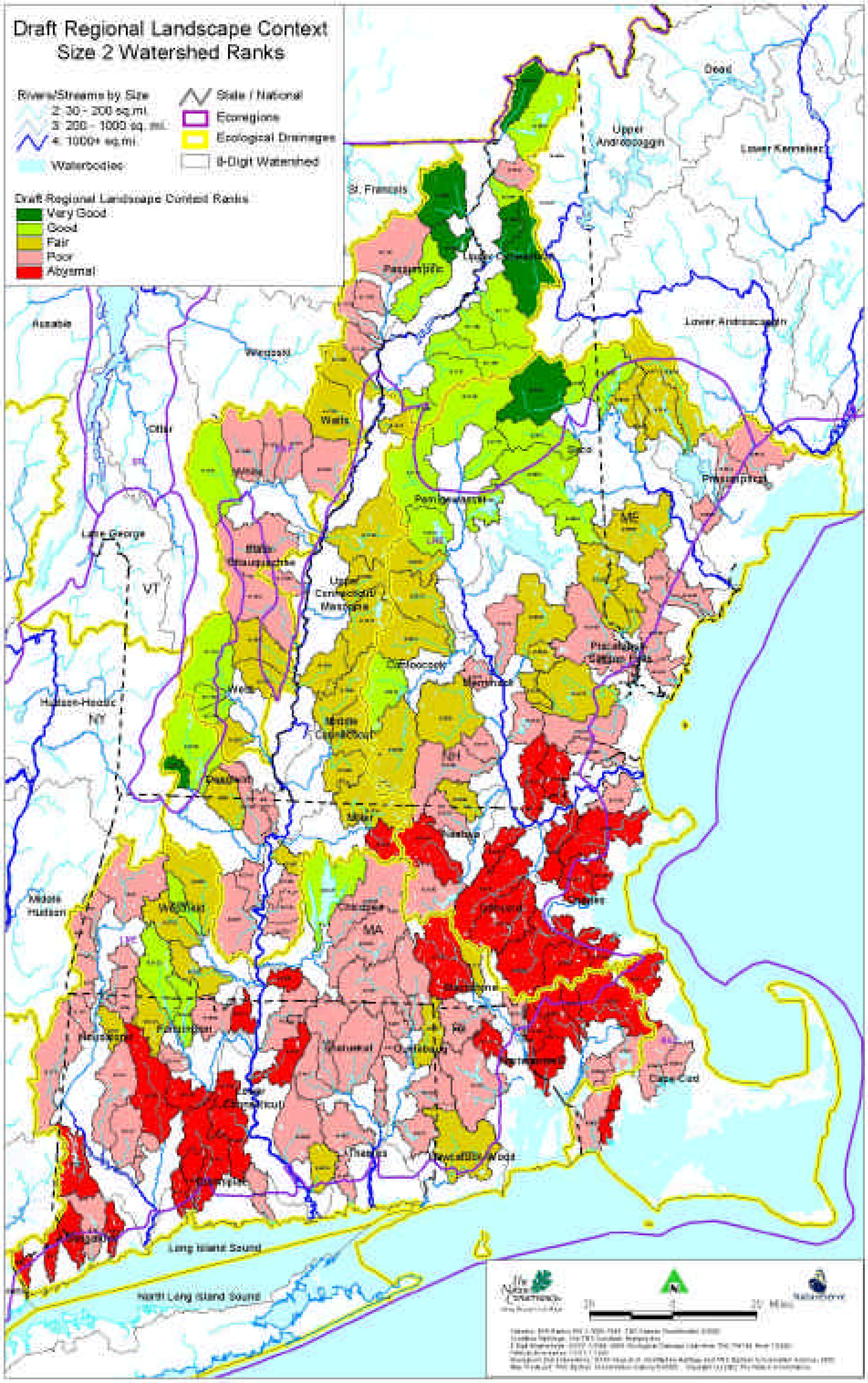


Table 10: Size 2 Watershed Landscape Context Ranking by Ecological Drainage Unit and Number and Percentage of Watersheds

# Size 2 Watersheds Falling into each category							% of Size 2 Watersheds Falling into each category						
Summary Rank	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total	Summary Rank	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total
1 (very good)	1		1	5		7	1	2	0	5	15	0	4
2 (good)	11	4	1	12		28	2	18	6	5	36	0	15
3(moderate)	17	9	11	5		42	3	28	13	50	15	0	22
4(fair-poor)	19	36	8	11	3	77	4	31	51	36	33	60	40
5 (very poor)	13	22	1		2	38	5	21	31	5	0	40	20
Grand Total	61	71	22	33	5	192	Grand Total	100	100	100	100	100	100

Table 11: Size 2 Watershed Percent Developed Ranking by Ecological Drainage Unit and Number and Percentage of Watersheds

# Size 2 Watersheds Falling into each category							% of Size 2 Watersheds Falling into each category						
%Developed	Saco-Merrimack-Charles (61_2)	Lower CT (61_6)	Middle CT (61_7)	Upper CT (63_2)	Cape Cod (62_3)	Grand Total	%Developed	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total
1: <1%	12	3	2	18		35	1	20	4	9	55	0	18
2: 1-2%	9	4	5	12		30	2	15	6	23	36	0	16
3: 2-6%	11	28	8	3		50	3	18	39	36	9	0	26
4: 6-15%	16	14	6		3	39	4	26	20	27	0	60	20
5: >15%	13	22	1		2	38	5	21	31	5	0	40	20
Total	61	71	22	33	5	192	Total	100	100	100	100	100	100

Table 12: Size 2 Watershed Road Density Ranking by Ecological Drainage Unit and Number and Percentage of Watersheds

# Size 2 Watersheds Falling into each category							% of Size 2 Watersheds Falling into each category						
Road Density (mi rd/sq.mi. watershed	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total	Road Density	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total
1: <1%	2		1	6		9	1	3	0	5	18	0	5
2: 1-2.5	19	11	7	26		63	2	31	15	32	79	0	33
3: 2.5-3.5	21	23	11	1	1	57	3	34	32	50	3	20	30
4: >3.5	19	37	3		4	63	4	31	52	14	0	80	33
								0	0	0	0	0	0
Total	61	71	22	33	5	192	Total	100	100	100	100	100	100

Table 13: Size 2 Watershed Percent Agriculture Ranking by Ecological Drainage Unit and Number and Percentage of Watersheds

# Size 2 Watersheds Falling into each category							% of Size 2 Watersheds Falling into each category						
% Agriculture	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total	% Agriculture	Saco-Merrimack-Charles	Lower CT	Middle CT	Upper CT	Cape Cod	Grand Total
1: <3%	7	2	1	10	1	21	1	11	3	5	30	20	11
2: 3-6%	13	7	3	7	2	32	2	21	10	14	21	40	17
3: 6-10%	29	25	10	5		69	3	48	35	45	15	0	36
4: >10%	12	37	8	11	2	70	4	20	52	36	33	40	36
								0	0	0	0	0	0
Total	61	71	22	33	5	192	Total	100	100	100	100	100	100

Dam Impacts

Table14: Dam Total Number and Density by River Size and Ecological Drainage Unit

EDU Dam Summary: # and density of dams on each size class river											
EDU	Total # dams	# dams per 10 sq.mi. of watershed	# dams per 10 miles of river	Total # dams on size 1	Total # dams on size 2	Total # dams on size 3	Total # dams on size 4	# dams on size 1 rivers per 10 miles of river	# dams on size 2 rivers per 10 miles of river	# dams on size 3 rivers per 10 miles of river	# dams on size 4 rivers per 10 miles of river
Saco	933	0.96	0.62	710	130	59	34	0.58	0.81	0.85	0.99
Lower CT	1480	1.61	1.07	1279	143	48	10	1.11	1.05	0.84	0.30
Middle CT	363	1.05	0.69	282	40	29	12	0.65	1.18	1.84	0.30
Cape	152	1.31	1.52	147	5			1.60	0.58		
Upper CT	176	0.38	0.39	129	24	17	6	0.36	0.45	0.75	0.43
Grand Total	3104	1.10	0.79	2547	342	153	62	0.78	0.87	0.93	0.51

Table 15: Dams by Type and Size within Ecological Drainage Units

EDU Dam Summary: Percentage of Dams within Summary Type and Size Categories										
EDU	Total # dams	%HYDRO ELECTRIC	%FLOOD CONTROL	% WATER SUPPLY	% RECREATION	%IRRIGATION	% OTHER	% <=15 feet high	% >15 feet and <= 50 feet high	% > 50 feet high
Saco	933	18	9	21	41	1	11	57	40	3
Lower CT	1480	5	4	23	55	3	10	45	49	6
Middle CT	363	18	3	15	54	1	9	39	54	7
Cape	152	2	4	7	25	61	1	79	21	0
Upper CT	176	19	6	9	54	0	13	39	53	9
Total %		11	6	20	49	4	10	49	46	5
Total # dams	3104	348	174	611	1520	138	313	1530	1422	152

Table 16: Dams on Size 2, 3,4 Rivers by Type

EDU Dams on Size 2, 3, 4 Rivers Summary: Percentage of Dams by Type Categories							
EDU	Total # dams	% HYDRO ELECTRIC	% FLOOD CONTROL	% WATER SUPPLY	% RECREATION	%IRRIGATION	% OTHER
Saco	223	55	14	4	18	0	8
Lower CT	201	29	7	23	21	0	19
Middle CT	81	63	6	5	21	1	4
Cape	5	20	0	0	20	60	0
Upper CT	47	62	9	2	13	0	15
Total %		47	10	11	19	1	12
Total # dams	557	263	56	61	107	4	66

Expert Interviews

452 expert interview site records were recorded as of 12/10/02. This represented interviews from over 85 individual experts. The sites were distributed as follows, 207 sites from Massachusetts, 95 sites from Connecticut, 21 sites from Rhode Island, and 129 sites from New Hampshire. Expert interviews were not conducted in VT because their recently completed Vermont Biodiversity Project provided the expert information needed. Expert interviews were also not completed for the coastal sections of Maine due to the desire of the Maine Chapter to gather expert interviews on these areas in late spring 2003.

Condition: Discussion and Conclusion

The overall landscape context non-system relative analysis highlighted the trend within the analysis area for the more northern and non-coastal areas to have better Landscape Context ranks. Over 80% of all watersheds in the Cape Cod EDU and Lower Connecticut EDU fell into the two most impacted categories, reflecting the high levels of urbanization and agriculture within these southerly and coastal EDUs. The Upper Connecticut EDU had the highest percentage of watersheds in the least impacted category 1 (15%) followed by the Middle Connecticut (5%) and Saco-Merrimack-Charles EDU (2%). Using the category where the highest percentage of watersheds in an EDU fell as a measure of the EDU's dominant condition, the Upper Connecticut EDU was predominantly good, the Middle Connecticut was moderate, Saco-Merrimack-Charles EDU was fair-poor, the Lower Connecticut was fair-poor, and Cape Cod was fair-poor.

In terms of the Landscape Context percent developed component, the Upper Connecticut EDU had the highest percentage of watersheds in the least impacted category 1 (55%), followed by Saco-Merrimack-Charles EDU (20%). The Cape Cod EDU had the highest percentage of watersheds in the most impacted category 5 (40%), followed by the Lower Connecticut EDU (31%). Numerous studies have found a negative relationship between the amount of catchment urban area and stream reach level aquatic Index of Biotic Integrity (IBI) scores (Jones and Clark 1987, Steedman 1988, Couch et al. 1997, Dreher 1997, Wang et al.,1997, Yoder et al. 1999, Gordon and Majumder 2000). Impervious surfaces associated with development are widely cited as major sources of non-point pollution such as sedimentation and alteration of the flow regime as water rapidly runs off relatively impervious surfaces, especially in storm or snowmelt events. The increased silt and sediment load increases turbidity in streams, alters nutrient levels and chemistry of water, reduces the quality of gravel spawning beds, and can change the distribution and distinction between riffle, pool, and run habitat. These changes have been linked to significant changes in the diversity and abundance of species (Berkman, and Rabeni 1987).

Urbanization also leads to development on floodplains, road building, destruction of riparian ecosystems, increasing demands for water uses, and the release of point source pollution to aquatic systems.

In terms of the Landscape Context Road Density component, the Upper Connecticut EDU had the highest percentage of watersheds in the least impacted category 1 (18%), followed by Middle Connecticut EDU (5%). The Cape Cod EDU had the highest percentage of watersheds in the most impacted category 4 (80%), followed by the Lower Connecticut EDU (52%). Watershed-wide road density has been found to be significantly negatively related to stream IBI (Bolstad and Swank 1997). The amount of road near streams has also been noted as an indicator contributing to lower IBIs (Moyle and Randall 1998, Arya 1999). Roads near stream channels tend to restrict a stream's lateral movement and keep it in a single channel. Fast channelized currents erode the stream bottom, cutting deeply into the stream bed lowering the elvation of the active channel. The deeper channel restricts movement of water into the floodplain negatively impacting floodplain communities and lowering the local water table. Culverts at road-stream crossings can pose a significant barrier to the movement of many types of aquatic biota that will not cross culverts due to the change in cover, substrate, and flow velocity. Roads also increase the amount of impervious surfaces in the watershed that increases non-point pollution such as sedimentation as water rapidly runs off.

In terms of the Landscape Context percent Agricultural ranking component, the Upper Connecticut EDU had the highest percentage of watersheds in the least impacted category 1 (30%) followed by Saco-Merrimack-Charles EDU (11%). The Lower Connecticut EDU had the highest percentage of watersheds in the most impacted category 4 (52%) followed by the Cape Cod EDU (40%). Runoff of fertilizers, pesticides, and herbicides are major sources of non-point pollution in agricultural watersheds. Agriculture increases nutrient levels due to fertilizers and animal wastes and by soil erosion increasing the transport of phosphorus. Grazing simplifies the riverine-riparian ecosystem as animals trample and consume riparian vegetation inhibiting regeneration of natural plant communities and increasing sedimentation rates. Depletion of riparian large wood debris leads to increased temperatures instream and depletion of instream large woody debris will alter channel stabilization, habitat pools, and sinousity.

A total of 3104 dams occurred in the analysis area with an average density of .79 dams per 10 stream mile or 1.01 dams per 10 square mile of watershed. The Upper Connecticut EDU had the lowest overall dam densities followed by the Saco/Merrimack/Charles, Middle Connecticut, Lower Connecticut and Cape EDU. The majority of the dams occurred on size 1 rivers, however the overall dam density per stream mile was higher on the size 2 (0.87) and size 3 (0.93) rivers than on the size 1 (0.78) or size 4 (0.51), indicating a higher level of overall fragmentation on these medium to large rivers. This pattern holds when looking within Ecological Drainage Units for the Saco/Merrimack/Charles, Upper Connecticut, and Middle Connecticut EDU; however, in the Lower Connecticut and Cape EDU the size 1 rivers have a higher dam density than the size 2 or 3 rivers. This may be due to the fact that these EDUs are generally much flatter than the other 3 EDUs and dominated by low and very low gradient larger rivers. In these EDUs, most moderate to high gradient segments, where significant gradient changes and thus good dam locations occur, are likely within size 1 streams. The pattern may also be due to the fact that these EDUs are much more highly settled than the other 3 edus and it is possible all the ideal dam locations on size 2 and 3 rivers were exploited and people began to build dams extensively even on smaller rivers.

Most of the dams in the analysis region were recreational dams (49%), followed by watersupply dams (20%), hydroelectric dams (11%), and flood control dams (6%). If only dams on the larger size 2-4 rivers are considered, the predominant type of dam changes, with hydroelectric dams making up 47% of the dams, followed by recreational (19%), water supply (11%), and flood control (10%). The Upper Connecticut, Middle Connecticut, and Saco/Merrimack/Charles EDU had the highest percentages of hydroelectric dams. Few very high dams (> 50 ft.) existed in the analysis region (5%) with the remaining dams relatively equally distributed between the lower dam (< 15ft) and moderate (>15 and <= 50) category. Of the very large dams, the majority are water supply (38%), followed by flood control (32%) and hydroelectric (20%).

Dams alter the structure and ecosystem functioning of a river as it is transformed from a continuous free-flowing system into river segments interrupted by impoundments. In addition to causing barriers to upstream and downstream migration and severing the river from it floodplain, dams cause a series of changes downstream and upstream from the impoundment including changes in flow, oxygen, temperature, and water clarity (Allen 1995). For example, dams that release high discharges cause the scouring of fine material, the compaction of the surface substrate below the dam, channel downcutting, and bank erosion. Rivers are also often deepened and widened in the impoundments behind dams altering temperature, oxygen, and sedimentation regimes. The size, purpose, and operation of dams also highly influence their impact on river systems. Hydroelectric dams are some of the largest dams and store water for release to meet specific energy demands that vary seasonally and throughout a 24 hour period. Daily fluctuations in energy demands usually cause operators to only allow water flow through the turbines from mid-morning through early evening. Run-of-the-river dams are usually of low height and are thought to have small adverse effects as they release water at the rate it enters the reservoir. Irrigation dams store as much water as possible during the rainy season for release during the growing season. Flood control reservoirs maintain only a small permanent pool in order to maximize storage capacity in case of a flood event. Navigation dams store water to offset low flow conditions and are complemented by a system of locks and other dams. Recreational and water supply dams usually store a certain amount of water during the rainy season to sustain reservoir capacity and have a variety of release management practices (Allen 1995).

Results of the system relative ordination analysis highlighted the top ranked watersheds in each size 2 system type in terms of the land cover and road axis, dam and drinking water supply axis, and point source axis. The results found very few watersheds fell in the top category for all three axes, making it difficult to select one single “best” watershed per system type via the GIS screening alone. This was expected because previous correlation analysis showed the land cover and road variables were not highly correlated with the dam and drinking water or point source variables. For example, only 2 of the 206 watersheds were ranked 1st in all three categories of land cover/road, dams/drinking water, and point source impacts. Excluding the point source ranking, only 9 watersheds (representing 4% of all watersheds, 36% of the 25 system types) were ranked both 1st in land cover/road and 1st in dams/drinking water impacts. 19 watersheds (representing 10% all watersheds, 76% of systems) were ranked 1st or 2nd in land cover/road and 1st or 2nd in dams/drinking water impacts. The top ranked (1) watersheds in the system-relative landcover and roads axis also varied widely in their overall Landscape Context rank from 1 (10% of all relative ranked 1 watersheds) through 2(30%), 3(27), 4(27%), to 5(7%). This highlighted the fact that some system types occurred entirely within very poor landscape context areas where even the best ranked watershed fell in overall landscape context category 4 or 5. These systems types occurred in the Lower Connecticut and Cape Cod EDU.

The expert interviews provided critical information regarding the biological diversity and condition of sites across the region. Although a standardized information form was used to collect the 452 expert interview site records, the varying background of the interviewees led to vast differences in the level of detail recorded on the interview forms. Many fields were left entirely blank on most interview forms, including in nearly all cases the ranking fields for size, condition, and landscape context. For example only 38 of the 452 had any landscape context ranks listed. The significant blanks in relation to some of these larger scale condition attributes highlighted the inability of most interviewees and TNC staff to put the described sites into size, condition, or landscape rank categories given the available information. Ranking required detailed knowledge of the desired native natural biotic community vs. the current biotic community, understanding of the current and natural flow regime, the ripairian and watershed condition around site, and the ability to compare the site to the existing range of quality among other sites over large spatial watershed scales. Despite these blanks, much useful information on local conditions and biological diversity was collected through this interview process. The information on the presence of particular species, biological communities, substrate diversity, temperature, flow, and other key ecological processes at the sites was particularly helpful because this information could not be gathered from GIS. In many cases information on exotic species and other local condition information such as dam management, bank stability, smaller local water withdrawals/well, and riparian buffer condition were noted.

Although exotic species could not be comprehensively evaluated for each size 2 watershed, nonindigenous species are a significant threat to aquatic ecosystems in this analysis area. Nonindigenous species have a number of negative impacts such as competition with indigenous species for food and habitat, reduction of natives by predation, transmission of diseases or parasites, hybridization, and habitat alteration. The USGS Nonindigenous Aquatic Species database (http://nas.er.usgs.gov) that records of all introduced, regardless of whether or not they because established, lists 94 introduced fish species in New England, with 25 of those species exotic to the region. The most widespread introduced fish species in New England include the bluntnose minnow, brown trout, burbot, cutlips minnow, fathead minnow, lake trout, largemouth bass, pearl dace, pumpkinseed, rainbow smelt, rainbow trout, rock bass, round-whitefish, and trout-perch. In addition to fish, a large number of nonindigenous species of other taxa such as plants, amphibians, reptiles, mammals, mollusks, crustaceans, and sponges have also entered aquatic systems and caused significant ecosystem alteration. For example in New England, the USGS database referred to above reports 9 (7 exotic) amphibians, 1 exotic jellyfish, 8 (2 exotic) crustaceans, 1 exotic byozoan, 15 (10 exotic) mollusks, 17 (5 reptiles), 4 (1 exotic) tunicate, and 23 aquatic vascular plants. Although these introductions have not all resulted in established populations, some of the most problematic and invasive species within the 5 EDUs include the asiatic clam, purple loosestrife, common reed grass, Eurasian water-milfoil, water-chestnut, yellow iris, curly pondweed, two-leaf water-milfoil, European water-clover, Carolina fanwort, watercress, Brazilian waterweed, dotted duckweed, pond water-starwort, and hydrilla. These species have or can significantly alter physical and biological functions of aquatic systems. For example, the water chestnut is a highly invasive species that can out-compete native plants, choke the waterbodies it invades, and reduce oxygen levels that increases the potential for fish kills. Similarly, Eurasian watermilfoil, a stringy submerged plant, can quickly proliferate and aggressively compete with native plant communities to form large dense mats that clog waterbodies. Purple Loosestrife, an invasive wetland perennial plant, will grow densely in shallow waterbodies or wetlands and can eliminate food and shelter for wildlife including shallow water fish spawning grounds. Curly pondweed, a submerged perennia, can tolerate low light and low water temperatures, making it competitively superior especially early in the season as it forms new plants under ice cover. Mid-summer die offs of this plant may result in a critical loss of dissolved oxygen and decaying plant matter can increase water nutrients and contribute to subsequent algal blooms.

Portfolio Assembly Results

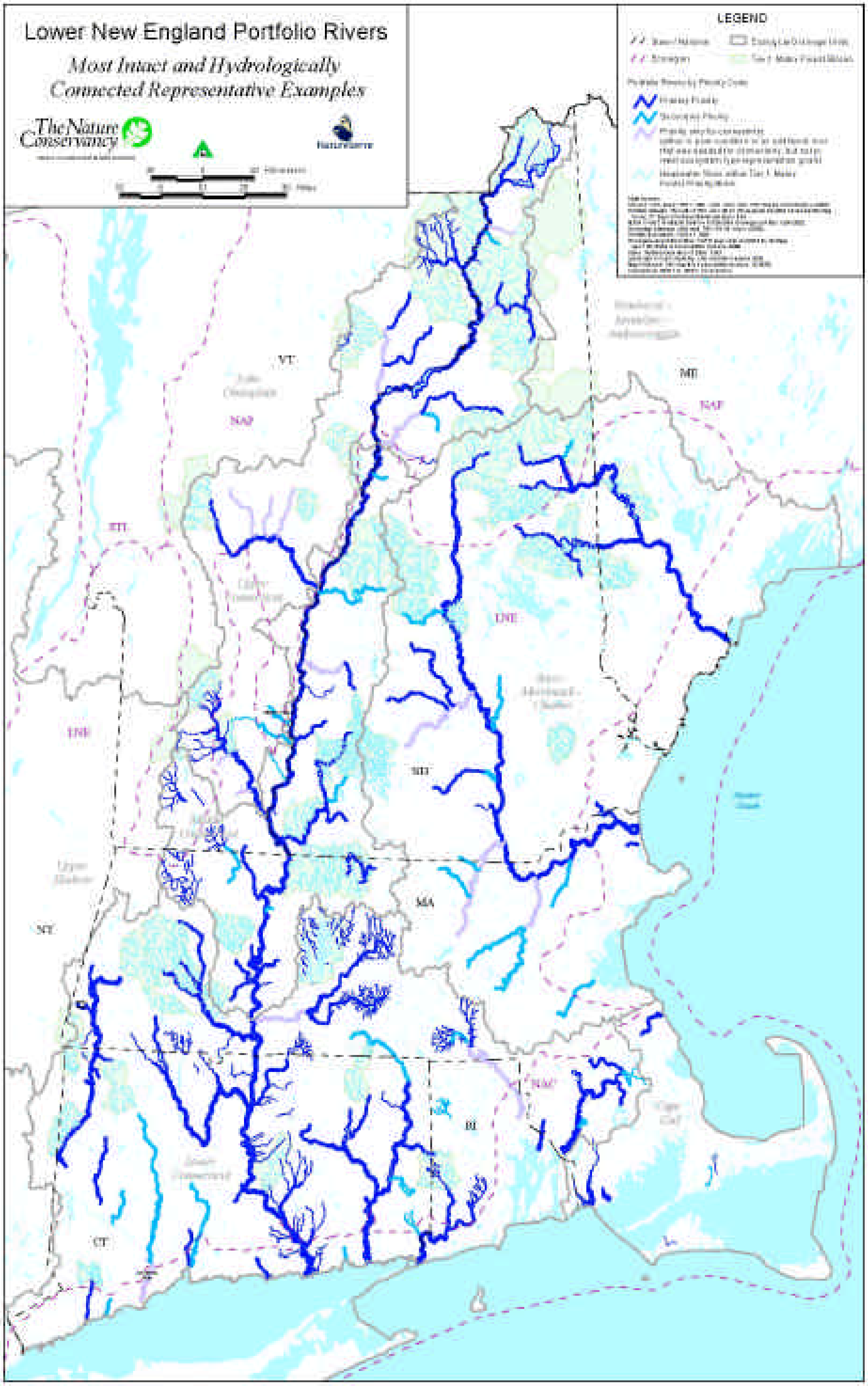
Portfolio Number and Miles

257 examples were selected for the portfolio (Table 17, Figure 11). These portfolio examples included 8140 stream miles. The decision was made to display the portfolio as line segments even though conservation of the portfolio will require watershed wide strategies. Note that the number of portfolio examples is larger than simply the number of named portfolio rivers because a portfolio river system that contained multiple size classes was broken at each size class for portfolio example record keeping. Thus, the Ashuelot River Size 1, Ashuelot River Size 2, and Ashuelot River Size 3 sections would be recorded as 3 portfolio examples, not simply one portfolio example. Named branches of rivers were also used to define portfolio example so the Westfield East Branch, Westfield Middle Branch, and Westfield West Branch were considered 3 examples even though they were all examples of a size 2_9 system type.

Table 17: Portfolio Examples by EDU, Portfolio Code, and Stream Size

Portfolio Milage by EDU, Portfolio Code, and Stream Size						
		SIZE				
EDUNAME	PORTCODE	1	2	3	4	Milage Totals
Cape Cod	S1c	15	38			53
	S2c	7				7
Cape Cod Total		23	38			60
Lower Connecticut	S1	162	55			216
	S1c	709	410	305	120	1543
	S2	28	13			41
	S2c	35	153	19		207
	S2m	763				763
	Sxc		2	69	13	85
Lower Connecticut Total		1697	632	393	133	2855
Middle Connecticut	S1	173	51			224
	S1c	22	114	27	203	366
	S2		13			13
	S2c		55			55
	S2m	886				886
	Sxc			18		18
Middle Connecticut Total		1080	233	45	203	1562
Saco-Merrimack-Charles	S1c	6	191	159	173	529
	S2c		184	6		190
	S2m	1364				1364
	Sxc			98		98
Saco-Merrimack-Charles Total		1371	375	263	173	2181
Upper Connecticut	S1	9				9
	S1c	178	228	111	95	612
	S2c	20	34			54
	S2m	684				684
	Sxc		79	44		123
Upper Connecticut Total		891	341	154	95	1481
Grand Total		5061	1619	856	604	8140

Figure 11: Aquatic Portfolio



Representation Goals

Representation goals were met for all systems except the NH/ME coastal systems where expert interviews are not complete. See Table 18 for a report of the number of portfolio examples selected within each System Type.

Table 18: Portfolio Examples by Type and Portfolio Code

SIZE/EDU/SYSTEM TYPE DOWN; PORTFOFOLIO CODE ACROSS; NUMBERS REPRESENT COUNT OF PORTFOLIO EXAMPLES CONTAINING THIS CATEGORY													
Size-System	S1	S1c	S2	S2c	Sxc	Grand Total	Size-System	S1	S1c	S2	S2c	Sxc	Grand Total
1	10	37	1	5		53	3_1					1	1
2_1		3				3	3_2					1	1
2_2		4		2		6	3_3						0
2_3		8		3	1	12	3_4				1		1
2_4		1		2		3	3_5		2				2
2_5		4		1		5	3_6		1				1
2_6		7		1		8	3_7					1	1
2_7	6					6	3_8		1				1
2_8	1		1	1		3	3_9		1			1	2
2_9		5				5	3_10		3		1		4
2_10	1	3	1			5	3_11		2			1	3
2_11	2	3		1		6	3_12		3				3
2_12		1		2		3	3_13		1				1
2_13		1		1	1	3	3_14		1				1
2_14		5		1	1	7	3_15		1				1
2_15		3				3	3_16		1				1
2_16		1			3	4	3_17					2	2
2_17	1	4		2	3	10	3_18					1	1
2_18		2				2	3_19		1			1	2
2_19		4		1		5	4		7			1	8
2_20		2		1		3	Grand Total	21	128	3	33	19	257
2_21						0							
2_22		2		2		4							
2_23		2		1		3							
2_24		1		4		5							

Connectivity Goals

180 of the 257 portfolio examples were part of a connected network. See the map of the portfolio, Figure 11 for a spatial representation of the network and non-network portfolio examples. The identified networks represent the team's estimation of the best representative river examples to focus on maintaining of developing functional networks for migratory fish. The 5 largest rivers in the analysis area, the Connecticut, Merrimack, Saco, Thames, and Housatonic were all chosen as important network portfolio examples, however only the lower section of the Housatonic was included due to the high level of fragmentation on the middle section of the Housatonic. Migratory target fish occurred in all of the size 3 river system types so the network goal was that all size 3 river systems required functional networks from larger river mouth to headwaters for migratory. See Table 19 regarding which migratory fish use which size 3 system types.

Table 19: Size 3 Watershed System Type by Migratory Fish

Sys. Size 3	ALEWIFE	AMERICAN EEL	AMERICAN SHAD	ATLANTIC SALMON	ATLANTIC STURGEON	BANDED KILLIFISH	BLUEBACK HERRING	FOURSPINE STICKLEBACK	GIZZARD SHAD	HICKORY SHAD	NINESPINE STICKLEBACK	RAINBOW SMELT	RAINWATER KILLIFISH	SEA LAMPREY	SHEEPSHEAD MINNOW	SHORTNOSE STURGEON	STRIPED BASS	WHITE PERCH	Grand Total
1	1	1	1			1	1	1		1	1	1		1			1	1	12
2		1				1													2
3	1	1	1	1		1	1	1		1	1	1		1			1	1	13
4	1	1	1	1	1	1		1			1			1		1	1	1	12
5	1	1	1			1	1					1		1			1	1	9
6			1	1														1	3
7	1					1												1	3
8	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	16
9	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	17
10	1	1	1		1	1	1											1	7
11		1				1													2
12		1	1	1		1	1							1				1	7
13	1	1	1		1	1												1	6
14		1	1	1	1	1	1							1		1		1	9
15		1		1		1								1					4
16		1		1		1													3
17		1	1	1		1	1					1		1				1	8
18		1		1															2
19		1		1								1							3
Grand Total	9	17	12	12	6	16	9	5	1	4	5	5	2	10	2	4	6	13	138

Networks were identified for all size 3 system types except system 3_3 which was a coastal Maine system that was not fully evaluated in this analysis due to lack of expert review in Maine and system 3_13 which was the Housatonic River whose mainstem is fragmented by a number of large reservoirs which the team felt were permanent barriers to developing a functional network. Although networks were identified for each system type, they vary in quality and many currently contain dams. For example, the only size 3 portfolio river with no dams on its mainstem to the ocean, potentially the most functional network example in the portfolio, is the Taunton River. Some rivers were included in the portfolio for connectivity purposes, but are were coded as Sxc because the team felt they did not meet the criteria for a S1 (best) or S2 (good/second best) rank within their system type given their current condition. These Sxc examples usually contain many dams or have other serious current condition problems making them poor examples of their type, but they are still necessary if functional networks are going to be restored for all size three system types. Sxc rivers that were identified as part of the portfolio include the Chicopee, Blackstone, Concord, Nashusa, Contoocook, Sugar, Ammonoosuc, Wild Ammonoosuc, Passumpsic.

Table 20: Size 3 Portfolio Network Examples

EDU	Lower Connecticut EDU	Downstream connectivity	Portfolio Code	Size 3 System Type
Lower Connecticut EDU	Chicopee	Connecticut	Sxc	11
Lower Connecticut EDU	Farmington	Connecticut	S1c	12
Lower Connecticut EDU	Westfield	Connecticut	S1c	12
Lower Connecticut EDU	Blackstone	Ocean	Sxc	9
Lower Connecticut EDU	Pawcatuck	Ocean	S1c	9
Lower Connecticut EDU	Quinebaug	Thames	S1c	10
Lower Connecticut EDU	Shetucket	Thames	S1c	10
Lower Connecticut EDU	Tauton	Ocean	S1c	8
Middle Connecticut	Ashuelot	Connecticut	S1c	14
Middle Connecticut	Sugar	Connecticut	Sxc	17
Upper Connecticut	Ammonoosuc	Connecticut	Sxc	17
Upper Connecticut	Passumpsic	Connecticut	Sxc	18
Upper Connecticut	Upper Ammonoosuc	Connecticut	Sxc	19
Upper Connecticut	West	Connecticut	S1c	15
Upper Connecticut	White	Connecticut	S1c	16
Saco/Merrimack/Charles	Concord	Merrimack	Sxc	1
Saco/Merrimack/Charles	Contoocook	Merrimack	Sxc	7
Saco/Merrimack/Charles	Nashua	Merrimack	Sxc	2
Saco/Merrimack/Charles	Pemigewasset	Merrimack	S1c	6
Saco/Merrimack/Charles	Piscataquog	Merrimack	S2	4
Saco/Merrimack/Charles	Ossipee	Saco	S1c	5
Saco/Merrimack/Charles	Saco River	Saco	S1c	5

Network were also identified for all size 2 system types except for system 2_7 which occurred in upper section of the Housatonic drainage. The team felt the large number of problems breaking the connectivity of the upper Housatonic from the lower Housatonic (dams, reservoir, contamination) make it unrealistic for the team to target this as a connected system in the near future. Note that the size 1 connected network has not been fully defined as the size 1 portfolio was not fully addressed in this analysis.

Threats Across the Portfolio

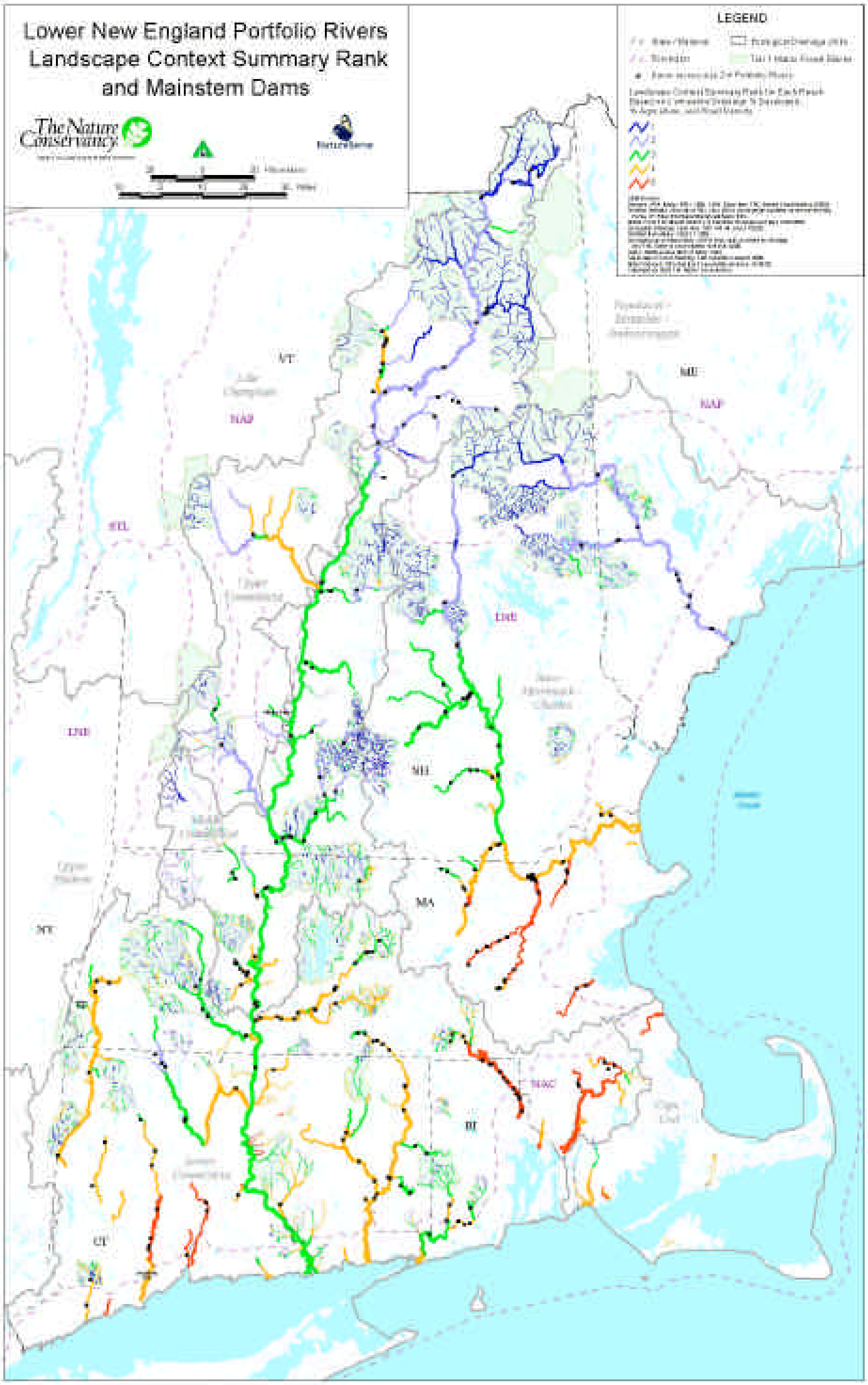
Impact from Non-Point Point Pollution

The portfolio examples varied significantly in overall landscape context rank within and between EDUs (Table 21, Figure 12). The data show that 13% of portfolio examples fall in the overall landscape context categories of very good (1) category, 22% fall in the good (2) category, 23% fall in the moderate/fair (3) category, 35% fall in the poor (4) category, and 8% fall in the very poor (5) category. The portfolio examples for size 1-3 rivers ranged across all landscape context ranking from very good (1) to very poor (5). The portfolio examples for size 4 rivers ranged from category 2-4. The Upper Connecticut and Middle Connecticut have no portfolio examples falling in the very poor category. The Cape Cod EDU and Lower Connecticut EDU have no examples falling in the very good (1) category. See PortfolioOccurrences.txt or .xls for a list of all portfolio examples by their Landscape Context Ranks.

Table 21: Portfolio Examples by EDU, Size, and Overall Range in Landscape Context Ranking

Portfolio Sites by EDU, Size, and Landscape Context Summary Rank							
EDUNAME	size	1	2	3	4	5	Grand Total
Cape Cod	1				3	1	4
	2				2	1	3
Cape Cod Total					5	2	7
Lower Connecticut	1		4	14	19	2	39
	2		2	11	25	8	46
	3			2	9	3	14
	4			1	2		3
Lower Connecticut Total			6	28	55	13	102
Middle Connecticut	1	2	6	6	5		19
	2	1	2	8	6		17
	3			2			2
	4			1			1
Middle Connecticut Total		3	8	17	11		39
Saco-Merrimack-Charles	1	5	6	1	3		15
	2	2	5	7	4	4	22
	3		3	1	2	1	7
	4		2		1		3
Saco-Merrimack-Charles Total		7	16	9	10	5	47
Upper Connecticut	1	14	12	2	1		29
	2	7	11	3	5		26
	3	1	3		2		6
	4		1				1
Upper Connecticut Total		22	27	5	8		62
Grand Total		32	57	59	89	20	257

Figure 12: Range in Portfolio Landscape Context Rank



Range in Landscape Context Ranking within EDU by Ecosystem Type

Review of the landscape context ranking within certain system types shows that certain systems are more heavily affected by the condition of the surrounding landscape. See the tables and summaries below for more information.

Table 22: Cape Cod Portfolio Landscape Context By System And Portfolio Code

Cape Cod EDU		Landscape Context Summary Rank		
SIZESYS	PORTCODE	4	5	Grand Total
1	S1c	3		3
	S2c		1	1
1 Total		3	1	4
2_1	S1c	2	1	3
2_1 Total		2	1	3
Grand Total		5	2	7

All the portfolio examples fall within the category 4 and 5.

Table 23: Lower Connecticut Portfolio Landscape Context By System And Portfolio Code

Lower Connecticut EDU		Landscape Context Summary Rank					
SIZESYS	PORTCODE	1	2	3	4	5	Grand Total
1	S1		1	2	2		5
	S1c		1	5	11	2	19
	S2			1			1
	S2c				2		2
	S2m		2	6	4		12
1 Total			4	14	19	2	39
2_2	S1c				1	3	4
	S2c				2		2
2_2 Total					3	3	6
2_3	S1c			5	3		8
	S2c				3		3
	Sxc					1	1
2_3 Total				5	6	1	12
2_4	S1c					1	1
	S2c					2	2
2_4 Total						3	3
2_5	S1c				2	1	3
2_5 Total					2	1	3
2_6	S1c			2	5		7
	S2c				1		1
2_6 Total				2	6		8
2_7	S1			1	5		6
2_7 Total				1	5		6
2_8	S1				1		1
	S2				1		1
	S2c				1		1
2_8 Total					3		3
2_9	S1c		2	3			5
2_9 Total			2	3			5

Lower Connecticut EDU		Landscape Context Summary Rank					
SIZESYS	PORTCODE	1	2	3	4	5	Grand Total
3_10	S1c				3		3
	S2c					1	1
3_10 Total					3	1	4
3_11	S1c			1	1		2
	Sxc				1		1
3_11 Total				1	2		3
3_12	S1c			1	2		3
3_12 Total				1	2		3
3_13	S1c				1		1
3_13 Total					1		1
3_8	S1c					1	1
3_8 Total						1	1
3_9	S1c				1		1
	Sxc					1	1
3_9 Total					1	1	2
4	S1c			1	1		2
	Sxc				1		1
4 Total				1	2		3
Grand Total			6	28	55	13	102

The Lower Connecticut EDU portfolio examples range from landscape context category 2-5, with most of the examples falling in category 4(54%) or 3(28%). Although a few Size 2 portfolio examples fall within the category 2, none of the Size 3 or 4 portfolio examples fall in a category higher than 3. Of the size 2 systems, only system 2_ 9 has any examples in the landscape context category 2; these being the Farmington West Branch and Westfield Middle Branch. Size 2 system types 2_3, 2_6, 2_7, 2_8, and 2_9 have some examples in landscape context category 3. Size 2 system types 2_2, 2_4, and 2_5 have all their portfolio examples in category 4 or 5, with all portfolio examples of system 2_5 in the lowest landscape context category 5. Of the size 3 systems, systems 3_8, 3_9, 3_10, and 3_13 are in the poorer condition, with the only example of system 3_8, the Tauton, in the lowest category 5.

Table 24: Middle Connecticut Portfolio Landscape Context By System And Portfolio Code

Middle Connecticut EDU		Landscape Context Summary Rank				
SIZESYS	PORTCODE	1	2	3	4	Grand Total
1	S1	1	1	2		4
	S1c		1	1	1	3
	S2m	1	4	3	4	12
1 Total		2	6	6	5	19
2_10	S1				1	1
	S1c				3	3
	S2			1		1
2_10 Total				1	4	5
2_11	S1		1		1	2
	S1c			3		3
	S2c			1		1
2_11 Total			1	4	1	6
2_12	S1c			1		1
	S2c		1	1		2
2_12 Total			1	2		3
2_17	S1	1				1
2_17 Total		1				1
2_5	S1c				1	1
	S2c			1		1
2_5 Total				1	1	2
3_14	S1c			1		1
3_14 Total				1		1
3_17	Sxc			1		1
3_17 Total				1		1
4	S1c			1		1
4 Total				1		1
Grand Total		3	8	17	11	39

The Middle Connecticut EDU portfolio examples range from landscape context 1 to 4, with the highest percentage in category 3 (44%). The portfolio examples in landscape context category 1 include 2 size 1 examples and the system 2_17 example in the upper West River watershed. Portfolio examples in landscape context category 2 include system 2_11 and 2_12. system Systems 2_5, 2_10, and 2_11 include portfolio examples in the lowest category of 4.

Table 25: Upper Connecticut Portfolio Landscape Context By System And Portfolio Code

Upper Connecticut EDU		Landscape Context Summary Ranking				
SIZESYS	PORTCODE	1	2	3	4	Grand Total
1	S1	1				1
	S1c	7	3	1		11
	S2c		1		1	2
	S2m	6	8	1		15
1 Total		14	12	2	1	29
2 13	S1c		1			1
	S2c		1			1
	Sxc		1			1
2 13 Total			3			3
2 14	S1c	4	1			5
	S2c	1				1
	Sxc				1	1
2 14 Total		5	1		1	7
2 15	S1c	2	1			3
2 15 Total		2	1			3
2 16	S1c		1			1
	Sxc				3	3
2 16 Total			1		3	4
2_17	S1c		4			4
	S2c			2		2
	Sxc		1	1	1	3
2 17 Total			5	3	1	9
3 15	S1c		1			1
3 15 Total			1			1
3 16	S1c				1	1
3 16 Total					1	1
3 17	Sxc		1			1
3 17 Total			1			1
3 18	Sxc				1	1
3 18 Total					1	1
3 19	S1c		1			1
	Sxc	1				1
3 19 Total		1	1			2
4	S1c		1			1
4 Total			1			1
Grand Total		22	27	5	8	62

Portfolio examples in the Upper Connecticut EDU range from 1-4, with the highest percentage in category 2 (44%) or 1(36%). System types 1, 2_14, 2_15, and 3_19 have portfolio examples in landscape context category 1. System types 2_13, 2_16, 2_17, 3_15and 3_17 have some portfolio examples in landscape context category 2. System types 2_16, 2_17, 3_18, and 3_16 have portfolio examples in the lowest category of 4, although these 2_16 and 2_17 portfolio examples are already coded Sxc.

Table 26: Saco-Merrimack-Charles Portfolio Landscape Context By System And Portfolio Code

Sum of count		LCR_SUM					
SIZESYS	PORTCODE	1	2	3	4	5	Grand Total
1	S1c				1		1
	S2m	5	6	1	2		14
1 Total		5	7	2	2		15
2_18	S1c		2				2
2_18 Total			2				2
2_19	S1c	2	2				4
	S2c		1				1
2_19 Total		2	3				5
2_20	S1c			2			2
	S2c			1			1
2_20 Total				3			3
2_22	S1c				2		2
	S2c			1	1		2
2_22 Total				1	3		4
2_23	S1c			2			2
	S2c				1		1
2_23 Total				2	1		3
2_24	S1c				1		1
	S2c					4	4
2_24 Total					1	4	5
3_1	Sxc					1	1
3_1 Total						1	1
3_2	Sxc				1		1
3_2 Total					1		1
3_4	S2c				1		1
3_4 Total					1		1
3_5	S1c		2				2
3_5 Total			2				2
3_6	S1c		1				1
3_6 Total			1				1
3_7	Sxc			1			1
3_7 Total				1			1
4	S1c		2		1		3
4 Total			2		1		3
Grand Total		7	16	9	10	5	47

Saco/Merrimack/Charles portfolio examples range from landscape context ranking 1-5, with the highest percentage in category 2 (34%). System types 1 and 2_19 have examples in category 1. System types 2_18, 3_5, and 3_6 have examples in category 2. System types 2_20, 2_22, 2_23, and 3_7 have examples in category 3. System types 2_24, 3_1, 3_2, and 3_4 have examples only on category 4 or 5, with the only portfolio example for system 3_1, the Concord, occurring in category 5.

Heavy Agricultural Impacts

136 (53%) portfolio examples fell within the Landscape Context Agricultural Impact Rank category 3 or 4. Of the 100 size 2+ portfolio examples in Landscape Context Agricultural Impact Rank category 3 or 4, 52 fell in category 3 and 48 fell in category 4. The 48 examples falling in category 4 are listed below. They occur in every EDU.

Table 27: Portfolio Size 2-4 Examples falling in Category 4 Heavy Agricultural Impacts

Portfolio Examples for Size 2-4 Rivers with Landscape Context Agricultural Rank 4 (> 10% agriculture in the watershed)								
SIZESYS	PORTCODE	EXAMPLENAME	PTOT_AGR	EDUNAME	CT	MA	NH	VT
2_1	S1c	Slocums River	12.03	Cape Cod		x		
2_1	S1c	West Port River	12.82	Cape Cod		x		
4	S1c	Thames River	13.36	Lower Connecticut	x			
4	Sxc	Housatonic River	14.73	Lower Connecticut	x			
3_13	S1c	Housatonic River	15.54	Lower Connecticut	x	x		
3_11	S1c	Quaboag River	14.33	Lower Connecticut		x		
3_11	Sxc	Chicopee River	10.25	Lower Connecticut		x		
3_10	S1c	Quinebaug River	12.95	Lower Connecticut	x			
3_10	S1c	Hop River / Willimantic River	12.90	Lower Connecticut	x			
3_10	S1c	Shetucket River	13.56	Lower Connecticut	x			
3_10	S2c	Naugatuck River	11.33	Lower Connecticut	x			
2_8	S1	Shepaug River	19.73	Lower Connecticut	x			
2_8	S2	Pomperaug River	20.37	Lower Connecticut	x			
2_8	S2c	Naugatuck River	12.98	Lower Connecticut	x			
2_7	S1	Blackberry River	10.51	Lower Connecticut	x			
2_7	S1	Green River	14.20	Lower Connecticut		x		
2_7	S1	Salmon Creek	17.62	Lower Connecticut	x			
2_7	S1	Williams River	12.47	Lower Connecticut		x		
2_7	S1	Schenob Brook	16.76	Lower Connecticut		x		
2_6	S1c	Salmon River	12.98	Lower Connecticut	x			
2_6	S1c	Quaboag River	15.03	Lower Connecticut		x		
2_6	S1c	Ware River	10.95	Lower Connecticut		x		
2_6	S1c	Hop River	11.76	Lower Connecticut	x			
2_6	S1c	Shetucket River	11.80	Lower Connecticut	x			
2_5	S1c	Coginchaug River	20.68	Lower Connecticut	x			
2_5	S1c	Scantic River	26.55	Lower Connecticut	x			
2_5	S1c	East Branch Salmon Brook	15.15	Lower Connecticut	x			
2_4	S2c	Mill River (Saugatuck Drainage)	10.60	Lower Connecticut	x			
2_4	S2c	Quinnipiac River	12.95	Lower Connecticut	x			
2_3	S1c	Queens River	10.35	Lower Connecticut				
2_3	S2c	Pachaug River	10.24	Lower Connecticut	x			
2_2	S1c	Palmer River	14.44	Lower Connecticut		x		
2_2	S2c	Winnetuxet River	10.19	Lower Connecticut		x		
2_5	S1c	Fort River	18.72	Middle Connecticut		x		
2_10	S1	Green River	10.58	Middle Connecticut		x		x
2_10	S1c	Manhan River	11.82	Middle Connecticut		x		
2_10	S1c	Roaring Brook	16.79	Middle Connecticut		x		
3_4	S2c	Piscataquog River	10.13	Saco-Merrimack-Charles			x	
3_2	Sxc	Nashua River	10.34	Saco-Merrimack-Charles		x	x	
2_24	S2c	Assabet River	10.90	Saco-Merrimack-Charles		x		
2_22	S1c	Baboosic Brook	11.22	Saco-Merrimack-Charles			x	
3_18	Sxc	Passumpsic River	10.43	Upper Connecticut			x	x
3_16	S1c	White River	12.78	Upper Connecticut				x
2_17	Sxc	White River, Third Branch	12.40	Upper Connecticut				x
2_16	Sxc	Passumpsic River	10.47	Upper Connecticut				x
2_16	Sxc	White River, First Branch	18.82	Upper Connecticut				x
2_16	Sxc	White River, Second Branch	23.36	Upper Connecticut				x
2_14	Sxc	Mohawk River	15.92	Upper Connecticut			x	
					21	18	5	7

Heavy Development and Road Impacts

146 (57%) portfolio examples fell within the Landscape Context Road Density or Development Rank categories 3, 4, or 5. Of the 97 size 2+ portfolio examples falling within the Landscape Context Road Density or Development Rank categories 3, 4, or 5, 51 fell in category 4 or 5 and 42 fell in category 3. The 51 examples falling in category 4 or 5 are listed below. They occur in all EDUs except the Upper Connecticut.

Table 28: Portfolio Size 2-4 Examples falling in Category 4 or 5 for Heavy Development and Road Impacts

Portfolio Examples for Size 2-4 Rivers with Landscape Context Road Density or Development Ranks 4 or 5 (>6% developed or > 3.5 miles roads/watershed sq.mi.)									
SIZESYS	PORTCODE	EXAMPLENAME	RD_SQMI	%DEV	EDUNAME	RI	CT	MA	NH
2_1	S1c	North River	5.09	23.71	Cape Cod			x	
2_1	S1c	Slocums River	3.88	14.85	Cape Cod			x	
2_1	S1c	West Port River	3.12	7.02	Cape Cod			x	
4	S1c	Thames River	3.57	6.91	Lower Connecticut		x		
4	Sxc	Housatonic River	3.84	9.88	Lower Connecticut		x		
3_9	S1c	Pawcatuck River	3.53	4.86	Lower Connecticut	x	x		
3_9	Sxc	Blackstone River	6.10	21.00	Lower Connecticut	x		x	
3_8	S1c	Taunton River	5.03	18.00	Lower Connecticut			x	
3_12	S1c	Farmington River	3.75	9.79	Lower Connecticut		x		
3_12	S1c	Westfield River	2.70	6.27	Lower Connecticut		x	x	
3_11	S1c	Quaboag River	3.62	6.51	Lower Connecticut			x	
3_11	Sxc	Chicopee River	3.17	6.41	Lower Connecticut			x	
3_10	S1c	Quinebaug River	3.57	6.70	Lower Connecticut		x		
3_10	S1c	Hop River / Willimantic River	3.53	7.00	Lower Connecticut		x		
3_10	S2c	Naugatuck River	5.66	19.20	Lower Connecticut		x		
2_8	S2	Pomperaug River	3.97	5.67	Lower Connecticut		x		
2_8	S2c	Naugatuck River	5.00	14.73	Lower Connecticut		x		
2_6	S1c	Salmon River	3.67	5.95	Lower Connecticut		x		
2_6	S1c	Quaboag River	3.51	5.69	Lower Connecticut			x	
2_6	S2c	Quinebaug River	3.79	7.64	Lower Connecticut		x	x	
2_5	S1c	Coginchaug River	5.82	28.16	Lower Connecticut		x		
2_5	S1c	Scantic River	3.71	11.55	Lower Connecticut		x		
2_4	S1c	Mill River (Quinnipiac Drainage)	7.95	40.04	Lower Connecticut		x		
2_4	S2c	Mill River (Saugatuck Drainage)	7.09	30.45	Lower Connecticut		x		
2_4	S2c	Quinnipiac River	7.37	37.57	Lower Connecticut		x		
2_3	S2c	Mumford River	3.50	8.05	Lower Connecticut			x	
2_3	S1c	Hammonasset River	3.98	5.29	Lower Connecticut		x		
2_3	S1c	Saugatuck River	5.13	12.57	Lower Connecticut		x		
2_3	S2c	Niantic River	3.40	7.88	Lower Connecticut		x		
2_3	Sxc	Blackstone River	6.62	26.48	Lower Connecticut			x	
2_2	S1c	Palmer River	4.78	16.04	Lower Connecticut	x		x	
2_2	S1c	Canoe River	4.81	20.28	Lower Connecticut			x	
2_2	S1c	Namasket River	3.54	7.51	Lower Connecticut			x	
2_2	S1c	Town River	5.16	20.56	Lower Connecticut			x	
2_2	S2c	Assonet	3.22	9.25	Lower Connecticut			x	
2_2	S2c	Winnetuxet River	3.47	9.65	Lower Connecticut			x	
2_5	S1c	Fort River	3.63	12.31	Middle Connecticut			x	
2_11	S1	Millers River, Upper Section	3.39	6.27	Middle Connecticut			x	
2_10	S1c	Manhan River	2.97	10.10	Middle Connecticut			x	
2_10	S1c	Mill River	2.88	9.30	Middle Connecticut			x	
4	S1c	Merrimack River	3.46	10.32	Saco-Merrimack-Charles			x	x
3_2	Sxc	Nashua River	4.41	13.97	Saco-Merrimack-Charles			x	x
3_1	Sxc	Concord River	6.16	23.77	Saco-Merrimack-Charles			x	
2_24	S1c	Parker River	4.15	12.03	Saco-Merrimack-Charles			x	

2_24	S2c	Assabet River	5.45	18.03	Saco-Merrimack-Charles			x	
2_24	S2c	Sudbury River	6.31	25.41	Saco-Merrimack-Charles			x	
2_24	S2c	Shawsheen River	9.12	43.65	Saco-Merrimack-Charles			x	
2_24	S2c	Neponset River	8.66	39.17	Saco-Merrimack-Charles			x	
2_22	S1c	Powwow River	4.29	12.91	Saco-Merrimack-Charles			x	x
2_22	S1c	Baboosic Brook	3.58	9.06	Saco-Merrimack-Charles				x
2_22	S2c	Squannacook River	3.47	6.87	Saco-Merrimack-Charles			x	
						3	20	31	4

Impact from Dams

Of the 257 portfolio examples, 184 examples (72% of all portfolio examples) had National Inventory of Dams (NID) dams within their upstream network. Of those 73 examples without dams fragmenting the upstream network, 68 (93%) of these examples were Size 1 examples, with 45 of these being S2M examples already within TNC priority forest matrix examples. Of the 5 non-size 1 portfolio examples without NID dams in their upstream network all 5 had a NID dam downstream before reaching the ocean.

Table 29: Portfolio Size 2-4 Examples without NID Dams in their upstream network with distance to nearest downstream dam

Portfolio Size 2 Examples without NID dams in their upstream watershed, by distance to nearest dam					Distanct to nearest downstream dam								
SIZESYS	PORTNAME	PORT CODE	SIZE_3	SIZE_4	none to ocean	0-4 mi.	5-9 mi.	9 - 14 mi.	15 - 19 mi.	20 - 29 mi.	30 - 39 mi.	40 - 49 mi.	50 mi. +
2_19	Saco River, East Branch	S2c		Saco					1				
2_17	Wardsboro Brook	Sxc		Connecticut							1		
2_16	Passumpsic River, East Branch	S1c		Connecticut		1							
2_15	Nulhegan River	S1c		Connecticut					1				
2_15	Nulhegan River, East Branch	S1c		Connecticut						1			

Considering just the medium to large portfolio rivers and just dams across their mainstem sections (not dams in their connected upstream size 1 network), of the 151 Size 2-4 portfolio examples, 69 (46%) had no dams on their mainstem sections. These examples included the above 5 above examples and the following 64 examples. However even though these 64 examples had no dams on their portfolio mainstem sections, 78% of these 64 examples had a dam downstream before reaching the ocean. The few portfolio rivers whose mainstems were not fragmented before reaching the ocean include the coastal size 2 rivers examples of the North, Slocums,West Port, Palmer, Hammonasset, Niantic, Mill, and Parker, the Eightmile tributary of the Connecticut, and the size 3 Taunton River and its size 2 tributaries of the Assonet, Namasket, and Winnetuxet. See Table 30 below for more information on distance to nearest dam downstream for the 64 examples that did not have a dam on their mainstem section.

Table 30: Size 2-4 Portfolio Examples without dams on their mainstem by Portfolio Code and Distance to nearest dam downstream

Portfolio Size 2-4 Examples without dams on their mainstem sections, by distance to nearest dam downstream					Distanct to nearest downstream dam								
SIZESYS	PORTNAME	PORT CODE	SIZE_3	SIZE_4	none to ocean	0-4 mi.	5-9 mi.	9 - 14 mi.	15 - 19 mi.	20 - 29 mi.	30 - 39 mi.	40 - 49 mi.	50 mi. +
Cape Cod													
2_1	North River	S1c		Ocean	1								
2_1	Slocums River	S1c		Ocean	1								
2_1	West Port River	S1c		Ocean	1								
Lower Connecticut													
2_2	Assonet	S2c	Taunton River	Ocean	1								
2_2	Namasket River	S1c	Taunton River	Ocean	1								
2_2	Palmer River	S1c		Ocean	1								
2_2	Winnetuxet River	S2c	Taunton River	Ocean	1								
2_3	Blackstone River	Sxc	Blackstone River	Ocean			1						
2_3	Eightmile River	S1c		Connecticut	1								
2_3	Hammonasset River	S1c		Ocean	1								
2_3	Niantic River	S2c		Ocean	1								
2_3	West River	S1c	Blackstone River	Ocean			1						
2_4	Mill River (Saugatuck Drainage)	S2c		Ocean	1								
2_5	East Branch Salmon Brook	S1c	Farmington River	Connecticut			1						
2_6	Hop River	S1c	Shetucket River	Thames				1					
2_6	Mount Hope River	S1c	Shetucket River	Thames		1							
2_6	Natachaug River	S1c	Shetucket River	Thames		1							
2_7	Blackberry River	S1	Housatonic River	Housatonic			1						
2_7	Green River	S1	Housatonic River	Housatonic					1				
2_7	Hollenbeck River	S1	Housatonic River	Housatonic		1							
2_7	Salmon Creek	S1	Housatonic River	Housatonic						1			
2_7	Schenob Brook	S1	Housatonic River	Housatonic					1				
2_7	Williams River	S1	Housatonic River	Housatonic						1			
2_8	Pomperaug River	S2		Housatonic			1						
2_9	Sandy Brook	S1c	Farmington River	Connecticut				1					
2_9	Westfield River, West Branch	S1c	Westfield River	Connecticut		1							
3_10	Hop River / Willimantic River	S1c	Hop River / Willimantic River	Thames			1						
3_11	Quaboag River	S1c	Chicopee River	Connecticut		1							
3_8	Taunton River	S1c	Taunton River	Ocean	1								
4	Housatonic River	Sxc		Housatonic	1								
Middle Connecticut													
2_11	Ashuelot River, South Branch	S1c	Ashuelot River	Connecticut		1							
2_11	Stockwell and Priest Brook	S1	Millers River	Connecticut		1							
2_12	Sugar River, South Branch	S1c	Sugar River	Connecticut				1					
2_17	Upper Deerfield Tributaries	S1	Deerfield River	Connecticut				1					
2_5	Fort River	S1c		Connecticut				1					
2_5	Sawmill River	S2c		Connecticut							1		
Saco-Merrimack-Charle													
2_18	Bear Camp River	S1c	Ossipee River	Saco			1						
2_18	Pine River	S1c	Ossipee River	Saco			1						
2_19	Pemigewasset River	S1c	Pemigewasset River	Merrimack						1			
2_19	Saco River	S1c	Saco River Size 3	Saco						1			
2_19	Swift River	S1c	Saco River Size 3	Saco				1					
2_20	Smith River	S2c	Pemigewasset River	Merrimack				1					
2_20	Warner River	S1c	Contoocook River	Merrimack			1						
2_22	Baboosic Brook	S1c	Souhegan River	Merrimack						1			
2_23	Soucook River	S2c		Merrimack			1						
2_24	Parker River	S1c		Ocean	1								
Upper Connecticut													
2_13	Wild Ammonoosuc River	Sxc	Ammonoosuc River	Connecticut		1							
2_14	Indian Stream	S1c	Connecticut River Size 3	Connecticut			1						
2_14	Mohawk River	Sxc	Connecticut River Size 3	Connecticut							1		
2_14	Nash Stream	S1c	Upper Ammonoosuc River	Connecticut		1							
2_14	Phillips Brook	S1c	Upper Ammonoosuc River	Connecticut				1					
2_14	Simms Stream	S2c	Connecticut River Size 3	Connecticut							1		
2_14	Upper Ammonoosuc River	S1c	Upper Ammonoosuc River	Connecticut		1							
2_15	Moose River	S1c	Passumpsic River	Connecticut		1							
2_16	White River, First Branch	Sxc	White River	Connecticut									1
2_16	White River, Second Branch	Sxc	White River	Connecticut									1
2_17	Saxtons River	S2c		Connecticut							1		
2_17	West River, Marlboro Brook	Sxc	West River	Connecticut					1				
2_17	West River, North Branch	S1c	West River	Connecticut							1		
2_17	White River	S1c	White River	Connecticut									1
2_17	Williams River	S2c		Connecticut		1							
2_17	Winhall River	S1c	West River	Connecticut			1						
3_15	West River	S1c	West River	Connecticut			1						
3_16	White River	S1c	White River	Connecticut								1	
					14	12	13	8	3	5	5	1	3

For the medium to large sized rivers, the 82 portfolio examples having dams on their size 2-4 mainstems were fragmented by 272 mainstem dams. 23 examples had dams over 50ft. high (32 dams) and 63 examples had dams between 15 and 50 feet (153 dams). The most frequent type of mainstem dam was a hydro dam, with 39 examples have a hydro dam on them (138 dams). Other common types of dams include 24 examples with flood control dams (33 dams), 20 examples with water supply dams (28 dams), and 31 examples with recreational dams (41 dams). See PortfolioOccurrences.txt or .xls for a column summarizing the number of dams on each portfolio example.

Table 31: Types and Sizes of Dams Across Portfolio Size 2-4 Mainstems

Number of Dams across the mainstems of size 2, 3, 4 Portfolio Rivers by EDU and Type

Ecological Drainage Unit	# NID Dams on size 2,3,4	<= 15 feet	>15 feet and <= 50 feet	> 50 feet	Hydroelectric	Flood control	Water supply	Recreation	Irrigation	Other
Lower Connecticut Summary	106	29	63	14	39	11	20	19	0	17
Middle Connecticut Summary	46	6	34	6	23	4	4	11	1	3
Saco-Merrimack-CharlesSummary	91	45	39	7	58	16	3	9	0	5
Upper Connecticut Summary	29	7	17	5	18	2	1	2	0	6
Totals	272	87	153	32	138	33	28	41	1	31

Ecological Drainage Unit	Total Height (ft.)	Maximum Height (ft.)	Total Storage (Acre-ft.)	Maximum Storage (acre-ft.)
Lower Connecticut Summary	3269	1826	705702	629273
Middle Connecticut Summary	1363	570	836817	227181
Saco-Merrimack-CharlesSummary	2080	860	617661	463299
Upper Connecticut Summary	1214	710	756254	443688
Totals	7926	3966	2916434	1763441

Portfolio Assembly: Discussion and Conclusion

Comprehensive conservation of aquatic biodiversity requires an understanding of the patterns of biodiversity and ecological processes operating at multiple scales. Aquatic landscape ecology has begun to focus on embracing the continuous, hierarchical and heterogeneous nature of aquatic habitats and in particular, 1) the consideration of aquatic conservation at multiple larger spatial and temporal scales, 2) the use of watersheds as more functional conservation units than reaches and 3) consideration of the connectivity in aquatic conservation assessments (Fausch et al 2002).

This new paradigm for aquatic conservation and stream fish ecology emphathizes a dynamic “riverine landscape” where connectivity is a critical environmental attribute. (Schlosser 1991, 1995, Schlosser and Angemeier 1995). This model notes the inherently patchy distribution of habitat features in aquatic systems at an intermediate scale and the necessity of stream fish to often move long distances to reach habitat patches required to complete their life history (for spawning, feeding, and rearing, refugia from disturbance, overwintering areas) and to maintain metapopulations through colonization and recolonization. Functional connectivity for aquatic systems is also important to protect key ecosystem processes such as water volume, flow rate, and flooding, that create and maintain the mixture of habitat patches needed. These processes are critical not only for maintaining instream habitat, but also on maintaining the riparian and floodplain communities and the complex interactions between the terrestrial and aquatic systems.

This conservation assessment’s goal to 1) assess and represent aquatic biota at multiple scales, particularly at scales above the reach or individual species and 2) to include identification of connected networks fits well with these recent developments in aquatic landscape ecology. By using a multiple scale watershed classification, this assessment attempted to include aquatic biological characteristics that are fully representative of an area. Watersheds and their network of streams, wetlands, and lakes were used as the conservation targets because many scientific studies have documented that riverine systems are intimately coupled with and created by the characteristics of their catchment basins or watersheds. For example, watersheds integrate processes that connect the longitudinal (upstream-downstream), lateral (floodplain-upland), and vertical (groundwater zone-stream channel) dimensions. This assessment also set initial minimum conservation goals to define the number and spatial distribution/connectivity of the examples needed in a conservation plan.

Although the identified conservation portfolio met representation goals for all evaluated size 2 and 3 systems and identified current or restorable connected networks for all except the size 2 and 3 systems in the upper Housatonic drainage, the current condition of the portfolio examples varies widely. Portfolio examples in the Upper Connecticut and Middle Connecticut have consistently better overall landscape context rankings than the Saco/Merrimack/Charles and Lower Connecticut and Cape EDU. For example, among the 60 size 2 and 3 portfolio examples in the Cape and Lower Connecticut EDU, only 2 had an overall landscape context rank of 2 or 1 and these were both in system 2_9 (Westfield River Middle Branch, Farmington River West Branch). By looking at the landscape context rankings by system type, one can see the portfolio examples in certain system types are more heavily impacted. For example, all portfolio currently occur in our lowest two landscape context categories (4,5) for systems 2_1, 2_2, 2_4, 2_5, 2_24, 3_2, 3_4, 3_8, 3_10, 3_13, 3_16, 3_18. Systems where all our portfolio examples occur in the overall landscape context categories 3 and 4 include 2_3, 2_6, 2_7, 2_8, 2_10, 2_5, 2_20, 2_22, 2_23, 3_7, 3_14, 3_17. Reviewing the components of landscape context responsible for the overall landscape context ranks of size 2-4 portfolio examples, shows a large number of portfolio examples fell in our lower two landscape context agriculture categories (53% of portfolio examples) and lower two developed/road impact categories (57% of portfolio examples), again highlighting the pervasive human settlement within the analysis region. Although we have yet to determine where the biological thresholds for agriculture and roads/development lie for our aquatic systems in lower New England, the data allows us to begin by highlighting where impacts from agriculture and development might be larger problems within our portfolio river systems.

Review of the current level of fragmentation among the portfolio sites in terms of dams, yields a similar sobering result. 72% of all portfolio river examples had National Inventory of Dams dam within their upstream network. Of the 5 non-size 1 (headwater) portfolio examples without NID dams in their upstream network all 5 had a NID dam downstream before reaching the ocean. Considering just the medium to large portfolio rivers and just dams across their mainstem sections (instead of also counting dams fragmenting headwaters that connect to these larger rivers), of the 151 Size 2-4 portfolio river examples, 69 (46%) had no dams on their mainstem sections. However, 78% of these 69 examples had a dam downstream before reaching the ocean. This left only 14 portfolio examples, 9-10% of all portfolio size 2-4 rivers, where all the size 2, 3, 4 portions of their portfolio mainstems were not interrupted by a dam before the ocean. The few portfolio rivers whose mainstems were not represenative of all river system types. For example, the 14 mainstem unfragmented dams include the direct to coast connected size 2 rivers examples of the North, Slocums, West Port, Palmer, Hammonasset, Niantic, Mill, and Parker. Only the Eightmile tributary of the Connecticut and the size 3 Taunton River and its size 2 tributaries of the Assonet, Namasket, and Winnetuxet were unfragmented larger size 3 or 4 river section networks. The 82 size 2-4 portfolio examples having dams on their size mainstems were fragmented by a total of 272 mainstem dams. 23 portfolio examples had dams over 50ft high. The most frequent type of mainstem dam was a hydro dam, with 39 portfolio examples have a hydro dam on them (138 dams). Although the National Inventory of Dams does not even include all of the small dams of less than 6 feet high, many of which also occur in New England, this review at least highlights where some of the lesser fragmented portfolio examples currently exist.

In conclusion, this assessment shows

1. There are a diversity of aquatic ecosystem types within and between EDUs in Lower New England. These types represent different aquatic environmental settings and are likely to have or develop different aquatic habitats and biotic assemblages over time given their unique environmental setting.
2. Threats to aquatic systems are enormous. Agriculture, development, roads, point sources, and dams have significant and pervasive impacts in the region, with some higher elevation and non-coastal systems being less impacted.
3. Few free flowing rivers exist in this region. The region has an average National Inventory of dam density was .79 dams per 10 stream miles, and this density would be significantly higher if all the smaller (<6ft , <50 acre-ft) dams were considered.
4. Even the “best examples”/portfolio examples of each system have significant impacts/problems. Many of the portfolio rivers are impacted by high levels of development. Although we tried to identify the best potential networks for migratory fish, currently few functional networks exist and the portfolio is highly impacted by dams. 90% of our size 2-4 portfolio rivers had a dam downstream before reaching the ocean and 54% of our size 2-4 portfolio river segments had a mainstem dam currently on the identified portfolio sections.

Future recommendations based on this analysis include the following:

- Test and refine TNC’s aquatic classification by compiling biological data sources (macroinvertebrate, herp., fishery data sets, etc.) to develop a more complete list of species and community targets within the classification types and to more fully integrate fish, macroinvertebrate, and other biological data into the classification.
- Refine GIS condition analysis and coordinate its use as a planning tool and as an adaptive tool to measure success at conservation areas and for TNC and partners.
- Identify and prioritize size 1 Aquatic Ecological Systems for conservation action.
- Conduct aquatic ecoregional planning for pond, lake, estuarine, and marine systems.
- Gather additional expert opinion data on aquatic systems and portfolio examples throughout the ecoregion by actively involving partners.
- Determine which dams have fish passage structures.
- Implement site conservation plans with detailed analysis of internal targets, key ecological factors, threats, and strategies for aquatic portfolio examples.

Future conservation strategies might include but not be limited to working with partners (Abell et al 2000) in order to:

- enact legislation that provides for the designation of freshwater systems as natural protected areas, particularly for the few remaining most intact and unaltered river systems.
- educate the public and policy makers about the biodiversity hidden from view in freshwater systems and the cumulative effects of land uses on downstream waters.
- promote conservation at the watershed scale, which requires cooperation and communication among multiple agencies with varying jurisdictions.
- reduce water consumption though implementation of sustainable agriculture and restrictions on nonessential water use and reducing groundwater pumping in sensitive areas.
- establish natural flow regimes in rivers by removing unneeded structures and modifying dam operations to resemble natural flow patterns.
- work to maintain and enforce legislation to protect federally listed species.
- prevent the introduction and spread of exotics into freshwater systems though public education and vigilant monitoring and enforcement.
- restore and protect riparian habitats by limiting grazing, promoting buffer strips, and restricting or promoting compatible development near stream and lake margins.
- work to reduce sedimentation associated with certain forms of logging, roads, and agriculture.
- reconnect stream reaches and drainage networks by removing impoundments, removing unneeded culverts, or creating structures to allow the passage of organisms and organic nutrients.
- remove flood-control structures in appropriate areas to allow for reestablishment of floods and maintenance of floodplain communities.
- restore and protect wetlands, which provide important filtering mechanisms for pollutants and contribute organic matter to freshwater systems.
- restore channelized streams to their original forms.
- remove or reduce point sources of pollution.