PLANNING METHODS FOR ECOREGIONAL TARGETS: FRESHWATER AQUATIC ECOSYSTEMS AND NETWORKS*

Introduction

Freshwater biodiversity conservation is vital to The Nature Conservancy's mission of biodiversity conservation. Compelling documentation of the perils facing freshwater biodiversity indicate that many of the most endangered species groups in the U.S. are dependent on freshwater resources. Approximately 70% of freshwater mussels, 52% of crayfish, 42% of amphibians and 40% of freshwater fish are classified as vulnerable or higher with respect to extinction risks. Additionally, water itself is a critical resource to terrestrial species and ecosystems and its patterns of drainage and movement have shaped the larger landscape in the Northeast.

Freshwater rivers, streams, lakes and ponds are diverse and complex ecological systems. Their permanent biota is comprised of fish, amphibians, crayfish, mussels, worms, sponges, hydras, hydromorphic plants, mosses, algae, insects, diatoms and a large number of microscopic protists adapted to life in freshwater. As with terrestrial species the patterns of species distributions occur at many scales and correspond both broad climatic and historic factors as well as very local factors such as stream size and velocity, bottom substrate, water chemistry and dissolved oxygen concentrations.

The objective of the freshwater analysis was to identify the most intact and functional stream networks and aquatic lake/pond ecosystems in such a way as to represent the full variety of freshwater diversity present within an ecoregion.

Geographic Framework for Aquatic Assessments

Patterns of freshwater diversity corresponds most directly with major river systems and the large watershed areas they drain. These drainage basins cut across the TNC Ecoregions that were developed based on terrestrial processes. In order to assess freshwater systems we needed a separate stratification framework of regions and drainage basins that made ecological sense for aquatic biodiversity patterns. To this end, we adopted an existing national map of freshwater ecoregions developed by the World Wildlife Fund[1] after Maxwell's Fish Zoogeographic Subregions of North America.[2] Within each freshwater ecoregion, the Nature Conservancy's Freshwater Initiative developed a further stratification level of Ecological Drainage Units. The

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* Olivero, A.P. (author) and M.G. Anderson, and S.L. Bernstein (editors). 2003. Planning methods for ecoregional targets: Freshwater aquatic ecosystems and networks. The Nature Conservancy, Conservation Science Support, Northeast & Caribbean Division, Boston, MA.

The standard methodologies sections created for this and all Northeast ecoregional assessment reports were adapted from material originally written by team leaders and other scientists and analysts who served on ecoregional planning teams in the Northeast and Mid-Atlantic regions. The sections have been reviewed by several planners and scientists within the Conservancy. Team leaders included Mark Anderson, Henry Barbour, Andrew Beers, Steve Buttrick, Sara Davison, Jarel Hilton, Doug Samson, Elizabeth Thompson, Jim Thorne, and Robert Zaremba. Arlene Olivero was the primary author of freshwater aquatic methods. Mark Anderson substantially wrote or reworked all other methodologies sections. Susan Bernstein edited and compiled all sections.

[1] Abell et al. 2000.

[2] Maxwell et al. 1995

Freshwater Ecoregions and Ecological Drainage Units together serves as an analog to the terrestrial ecoregions and subsections for the Northeast.

Zoogeographic Subregions/Freshwater Ecoregions: describe continental patterns of freshwater biodiversity on the scale of 100,000-200,000 sq. miles. These units are distinguished by patterns of native fish distribution that are a result of large-scale geoclimatic processes and evolutionary history.[3] For North America, we adopted the freshwater ecoregions developed by the World Wildlife Fund.[4] Examples include the St. Lawrence Subregion, North Atlantic to Long Island Sound Subregion, Chesapeake Bay Subregion, and South Atlantic Subregion.

Ecological Drainage Units (EDUs): delineate areas within a zoogeographic sub-region that correspond roughly with large watersheds ranging from 3,000–10,000 square miles. Ecological drainage units were developed by aggregating the watersheds of major tributaries (8 digit HUCs) that share a common zoogeographic history as well as local physiographic and climatic characteristics. These judgements were made by staff of TNC's Freshwater Initiative after considering USFS Fish Zoogeographic Subregions, USFS Ecoregions and Subsections, and major drainage divisions.[5] Ecological drainage units are likely to have a distinct set of freshwater assemblages and habitats[6] associated with them. Depending on the amount of ecological variation within them, some large river systems such as the Connecticut River were divided into more than one EDU.

Finer-Scale Classification of Aquatic Ecosystems and Networks

Within the geographic framework of the zoogeographic subregions and ecological drainage units there exits a large variety of stream and lake types. If you contrast equal sized streams, some develop deep confined channels in resistant bedrock and are primarily fed by overland flow while others are fed by groundwater and meander freely through valleys of deep surficial deposits. Variation in the biota also exists as the stream grows in size from small headwater streams to large deep rivers near the mouth. We needed a way to systematically describe and assess the many types of stream networks and aquatic features that was both ecologically meaningful and possible to create and evaluate in an 18 month time frame. For these purposes, and in conjunction with the Freshwater Initiative, we developed a multiple scale biophysical watershed and stream reach classification within Ecological Drainage Units. This classification framework is based on three key assumptions about patterns in freshwater biodiversity.[7]

- Aquatic communities exhibit distribution patterns that are predictable from the physical structure of aquatic ecosystems[8]
- Although aquatic habitats are continuous, we can make reasonable generalizations about discrete patterns in habitat use and boundaries distinguishing major transitions[9]
- By nesting small classification units (watersheds, stream reaches) within large climatic and physiographic zones (EDUS, Freshwater Ecoregions), we can account for community

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[3] Maxwell et al. 1995
[4] Abell et al. 2000
[5] Higgens et al. 2002
[6] Bryer and Smith 2001
[7] Higgins et al. 1998
[8] Schlosser 1982; Tonn 1990; Hudson et al. 1992
[9] Vannote et al. 1980; Schlosser 1982; Hudson et al. 1992

diversity that is difficult to observe or measure (taxonomic, genetic, ecological, evolutionary context)[10]

Multiple-Scale Watershed Classification: Aquatic Ecological System Types: Watersheds contain networks of streams, lakes, and wetlands that occur together in similar geomorphologic patterns, are tied together by similar ecological processes or environmental gradients, and form a robust cohesive and distinguishable unit on a map. When a group of watersheds of similar size occur under similar climatic and zoographic 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 biodiversity patterns patterns.[11] The following four primary physical classification variable were chosen for use in the watershed classification because they have been shown to strongly affect the form, function, and evolutionary potential of aquatic systems at watershed level scales.

Primary Classification Variables

1. Size: Stream size influences flow rate and velocity, channel morphology, and hydrologic flow regime.
2. Elevation Zones: Elevation zones corresponds to local variation in climate. Climatic differences are correlated with differences in forest type, types of organic input to rivers, stream temperature, flow regime, and some aquatic species distribution limits.
3. Geology: Bedrock and surficial geology influence flow regime through its effect on groundwater vs. surface water contribution, stability of flow, water chemistry, sedimentation and stream substrate composition, and stream morphology.
4. Gradient and Landform: Gradient and landform influence stream morphology (confined/meandering), flow velocity, and habitat types due to differences in soil type, soil accumulation, moisture, nutrients, and disturbance history across different landforms. For example, the morphology of streams differs substantially between mountains and lowland areas due to contrast in the degree of landform controls on stream meandering. Lower gradient streams also vary in substrate composition, as in New England, low gradient streams typically have sand, silt and clay substrates while high gradient streams typically have cobble, boulder, and rock substrates.

Stream size is among the most fundamental physical factors related to stream ecology. The *river continuum concept* provides a qualitative framework to describe how the physical size of the stream is related to river ecosystem changes along the longitudinal gradient between headwaters and mouth.[12] See Figure 1 at the end of this chapter for an illustration of the river continuum concept.

Stream size measures based on drainage area are highly correlated with other recognized measures of stream size such as stream order, the number of first order streams above a given segment, flow velocity, and channel. In the Northeast U.S., TNC used the following stream size

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[10] Frissell et al. 1986; Angermeier and Schlosser 1995
[11] 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
[12] Vannote et al. 1980

classes: size 1) headwaters to small streams with 0-30 sq. mi. drainage areas, size 2) medium streams with 30-200 sq. mi. drainage areas, size 3) large mid-reach streams and small rivers with 200-1000 sq. mi. drainage areas; and size 4) very large river systems with > 1000 sq. mi. drainage areas. For different landscapes and regions, ecologically significant class breaks in stream size can differ, but relationships between stream size and potential river reach ecosystems appear to hold. For example relationships between stream size, stream order, and reach level community types in the Northeast are as follows:

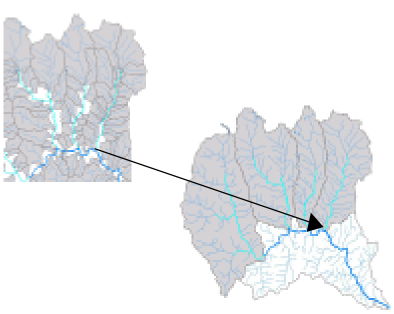
Table 1: Generalized Stream Size and Community Relationships

STREAM SIZE	STREAM ORDER	Stream reach level community occurrence
1	1-2	Rocky headwater
1(2)	1-3	Marshy headwater
2,3	3-4	Confined river
3,4	4+	Unconfined river

See the Appendix at the end of this chapter for more detailed descriptions of potential biological assemblages of fish, macroinvertebrates, and plants associated with specific types of the above generalized stream community types in Vermont.

Watersheds of streams in the four size classes were used as system classification units. These units serve as "coarse filters" to represent the species, ecological processes, and evolutionary environments typical of that size stream network or watershed. Watersheds are defined as the total area draining to a particular river segment. Watersheds themselves are a physically defined unit, bounded by ridges or hilltops. We derived a set of watersheds in GIS for each river segment. The individual reach watersheds were then agglomerated into larger watershed sampling units. Watersheds were agglomerated above the point where a stream of a given size class flowed into a stream of a larger size class. The resultant watersheds represented the direct drainage area for each river in a size class. The agglomerated watersheds were used as sampling units in the further size 1, size 2, size 3, and size 4 system classification.

Example of how size 1 watersheds are agglomerated into size 2 watersheds at the point where a size 2 river merges into a size 3 river.



Watersheds were grouped into similar aquatic system groups within each size class according to the physical characteristics of bedrock and surficial geology, elevation, and landform within the watershed. A statistical analysis of the elevation, geology, and landform landscape characteristics within each watershed was performed by sampling the Ecological Land Units (ELUs) within watersheds. The ELU dataset classifies each 90m cell in the landscape according to its elevation zone, bedrock and surficial geology, and landform. Elevation zones were based on the general distribution of dominant forest types in the region, as this climax vegetation provides a proxy for the climatic variation across the region. The bedrock and surficial geology classes were based on an analysis of the ecological properties of bedrock and soils in terms of chemistry, sediment texture, and resistance.[13] The bedrock included acidic sedimentary and metasedimentary rock, acidic granitic, mafic/intermediate granitic, acidic shale, calcareous, moderately calcareous, and ultramafic bedrock. The surficial types included coarse or fine surficial sediment. The landform model was developed by M. Anderson according to how terrestrial communities were distributed in the landscape. The landform model had 6 primary units (steep slopes and cliffs, upper slopes, side slopes and coves, gently sloping flats, flats, and hydrologic features) that differentiate further into 17 total landform units. Landforms control much of the distribution of soils and vegetation types in a landscape as each different landform creates a slightly different environmental setting in terms of the gradient, amount of moisture, available nutrients, and thermal radiation. The results of the statistical cluster analysis (TWINSPAN), was adjusted by hand, to yield a final set of watershed aquatic ecological system types which were used as the coarse filter aquatic targets.[14]

Figures 2 and 3 below show an example landscape with superimposed ELUs, watersheds, and derived watershed system types. The Moosup and Pachaug watersheds are imbedded in a very similar landscape dominated by acidic granitic bedrock, low elevation flats and gentle hills, large areas of wet flats and coarse grained sediment flats along the rivers. The Westfield Middle Branch watershed is located in a very different landscape dominated by acidic sedimentary bedrock, gentle hills and sideslopes ranging from low to mid elevation, fewer areas of wet flats, more confined channels, and higher gradient streams. The Moosup and Pachaug would serve as interchangeable members of size 2 watershed system type 3, while the Westfield would represent a different size 2 watershed system type of 9. We would expect these systems to have different aquatic habitats and ecological potentials due to their different environmental setting.

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[13] Anderson 1999

[14] For more information on the detailed GIS and statistical methods used to build the stream network, stream reach classification, and watershed classification, see Olivero 2003.

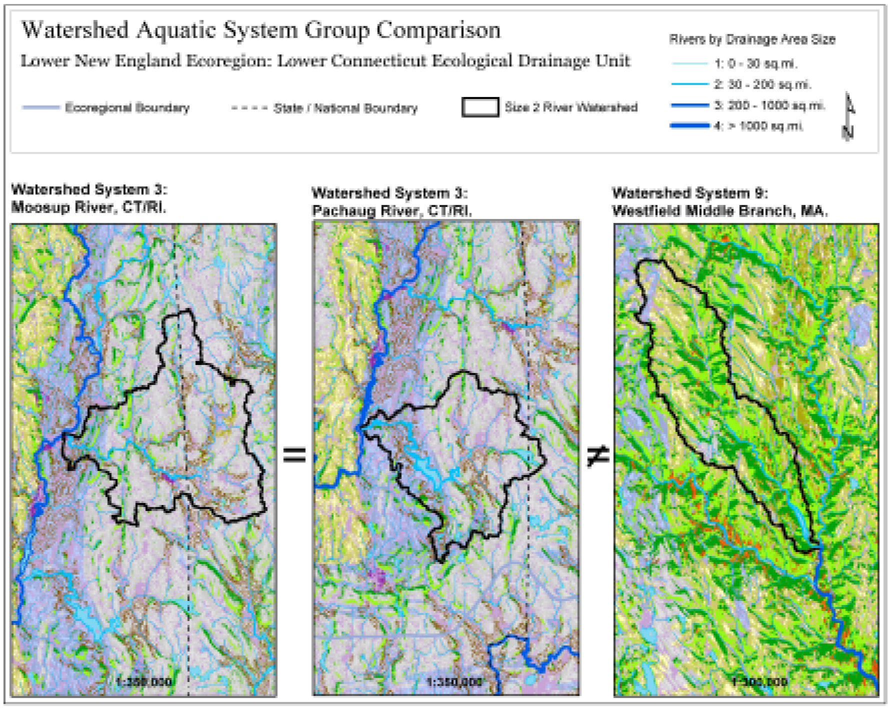

Figure 2: Watershed Aquatic System Group Comparison

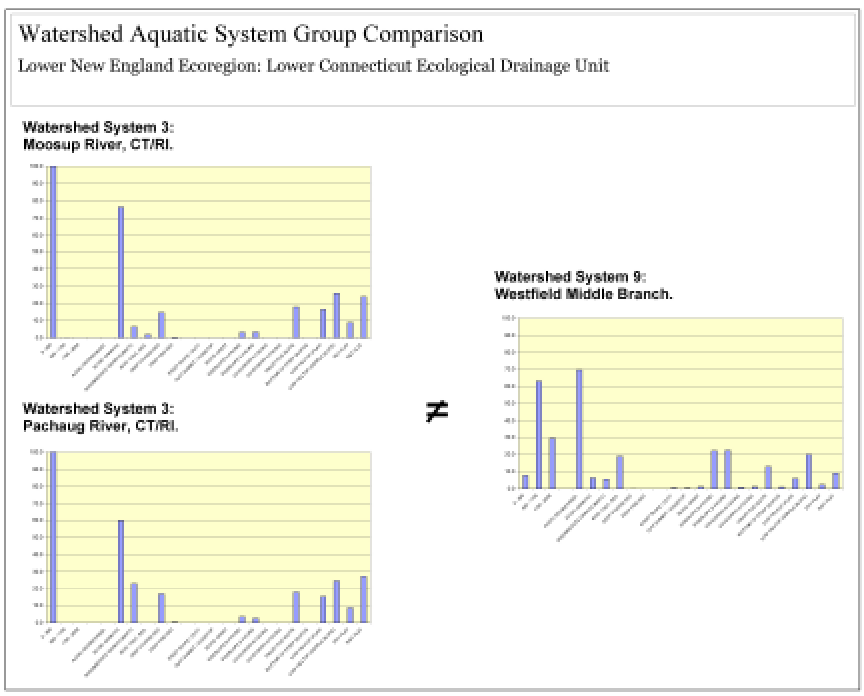

Figure 3: Watershed Aquatic System Component Summary

Stream Reach Classification: Macrohabitats A reach is defined as the individual segment of a river between confluences or as the shoreline of a lake. A stream reach classification was performed using physical variables known to structure aquatic communities at this scale and that can be modeled in a GIS. These variables include factors such as stream or lake size, gradient, general chemistry, flashiness, elevation, and local connectivity[15]. The physical character of macrohabitats and their biological composition are a product of both the immediate geological and topographical setting, as well as the transport of energy and nutrients through the systems. Macrohabitats represent potential different aquatic communities at the reach level and are useful on ecoregional and site conservation planning as a surrogate for biological aquatic communities at this scale

Table 2 : Macrohabitat Classification

Driving processes, modeled variables, GIS datasets, and modeled classes used to define Macrohabitats.[16]

Ecosystem Attribute	Modeled Variable	Spatial Data	Classes/Glass Breaks
Zoogeography	1) Region 2) Local Connectivity	1) Ecological Drainage Unit 2) Hydrography	1) Ecological Drainage Unit break 2) upstream and downstream connectivity to 1 = stream, 2=lake, 3=ocean
Morphology	1) Size (drainage area) 2) Gradient	Hydrography and DEM	1) 0-30 sq. mi., 30-200 sq. mi., 200-1000 sq. mi., > 1000 sq. mi. 2) 1=0-.5%, 2=.5-2%, 3=2-4%, 4=4-10%, 5=>10%
Hydrologic Regime	Stability/Flashiness and Source	Hydrography, Physiography, Geology	Stable or Flashy (complex rules based on stream size, bedrock, and surficial geology)
Temperature	Elevation	DEM	1=0-800ft 2=800-1700ft 3=1700-2500ft 4=2500ft+ [17]
Chemistry	Geology and Hydrologic Source	Geology	is cal-neutral for size 1-2's if > 40% calcareous; is cal-neutral for size 3-4's if 30% is calcareous

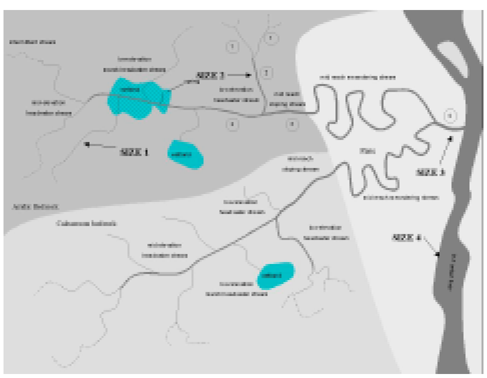

Figure 4: Anatomy of a Stream Network Macrohabitat Model

Selecting Aquatic Targets

The team selected both fine scale and coarse scale conservation targets. The aquatic fine-scale species targets such as rare and declining species (e.g. dwarf wedgemussel) are discussed in the section of this plan on Species Targets. In addition to rare and declining species, aquatic species

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[15] The macrohabitat model is based on work done by Seelbach et al. 1997, Higgins et al. 1998, and Missouri Gap Valley Segment Classification 2000.

[16] See the documentation on TNC Freshwater Initiative web site's science page (www.freshwaters.org) or the methods section of Olivero 2003 for more information on the GIS tools and scripts used to develop these attributes.

[17] Breaks from ecoregional ELU analysis

targets should also include consideration of regional-scale migratory fish (e.g., Atlantic salmon) whose life history needs extend beyond the boundaries of the planning area and who may face a unique set of threats (e.g. lack of fish passage at mainstem dams).

The focus of our coarse filter target selection was the watershed size 2 and size 3 level aquatic system classification. The size 2 and 3 watersheds were chosen as the coarse scale targets because 1) they represented an intermediate scale of river system which recent literature has emphasized as the scale where many processes critical to populations and communities occur,[18] 2) the size 1 watersheds and reach classification were well correlated with the larger scale size 2 and 3 watershed types, and 3) they provided management "units" around which TNC felt the core of a site conservation planning effort would operationally develop.

Setting Goals

Goals in ecoregional planning define the number and spatial distribution of on-the-ground occurrences of conservation targets that are needed to adequately conserve the target in an ecoregion. Setting goals for aquatics biophysical systems in ecoregional planning is a much less well developed process than setting goals for terrestrial communities because we have not yet defined the exact biological communities associated with each watershed ecosystem type.

In terrestrial settings, the minimum number of viable occurrences needed in the portfolio for each terrestrial community is related to the patch size and restrictedness of the target. The minimum number of occurrences needed is determined by the relative increase in probability of environmental or chance events reducing the ecological integrity of the target community. Because we have not developed biological community descriptions of our surrogate coarse filter watershed system targets, and as a result have not applied specific biologically based viability standards to these targets; the TNC team set conservative initial minimum goals.

Representation Goals

An initial minimum representation goal of one example of each size 2 and size 3 watershed type was set. It is unlikely one example is truly enough for all watershed ecosystem types, so the ecoregional team was allowed to use their professional judgement to add additional examples of system types into the portfolio given that 1) the team had strong feelings other examples were needed to represent the diversity within the system, 2) there were equally intact interchangeable units for which priority of one or the other could not be decided, or 3) if there were other compelling reasons to include more examples of a system type (i.e. additional very critical area for species level aquatic target; could create a good terrestrial/aquatic linkage; another example was needed to fill out regional connectivity network; active partners already working on the example and TNC could gain partnerships by expanding our work and including this example even if it wasn't the most intact example).

More specific abundance goals will have to be set in future iterations of the plan once the biological descriptions and distinctiveness between and within watershed types are more fully understood. Research should also be done to determine how the changes in number of examples of various size classes influences how many examples of each size class should be included in the portfolio.

[18] Fausch et al 2002

Connectivity Goals

Connectivity of aquatic ecological systems is based on the absence of physical barriers to migration or water flow. Connectivity is of critical importance for viable regional and intermediate-scale fish and community targets and for maintaining processes dependent on water volume and flooding. The regional scale connectivity goal was to provide at least one “focus network” of connected aquatic ecological systems from headwaters to large river mouth for each size 3 river type where a regional wide-ranging species was present. A secondary intermediate scale connectivity goal was to provide the best pattern of connectivity for intermediate-scale potadromous fish, intermediate scale communities, and processes. The goal for these intermediate scale targets was to provide at least one connected suite of headwaters to medium sized river. Again, here the focus was on functional connections at the mouth of a size 2 river and some functional connections from the size 2 to its size 1 tributaries.

Assessing Viability

Viability refers to the ability of a species to persist for many generations or an Aquatic Ecological System to persist over some specified time period. In aquatic ecosystems, viability is often evaluated in the literature by a related term “biotic integrity”. Biotic integrity is defined as the ability of a community to support and maintain a balanced, integrated, adaptive community of organisms having species compositions, diversity, and functional organization comparable to that of a natural habitat of the region.[19]

A myriad of anthropogenic factors contribute to lower viability and biologic integrity of aquatic systems. Dams and other hydrologic alteration, water quality degradation from land use change, and introduced species all have well documented negative impacts on the structure and functioning of aquatic ecosystems. Dams alter the structure and ecosystem functioning by 1) creating barriers to upstream and downstream migration, 2) setting up a series of changes upstream and downstream from the impoundment including changes in flow, temperature, water clarity; and 3) severing terrestrial/aquatic linkages critical for maintaining the riparian and floodplain communities. The spread of human settlement has intensified agriculture, road building, timber harvest, draining of wetlands, removal of riparian vegetation, and released many harmful chemicals into the environment. This land use alteration has led aquatic habitats to become fragmented and degraded through increased sedimentation, flow and temperature regime alteration, eutrophication, and chemical contamination. Introduced nonindigenous species have also had negative impacts as they compete with indigenous species for food and habitat, reduce native populations by predation, transmit diseases or parasites, hybridize, and alter habitat. Introductions and expansions of nonindigenous species are causing an increasing threat to aquatic systems and are usually extremely difficult if not impossible to undo.

Quality Assessment

Assessing the viability and condition of the coarse scale watershed system targets presented a unique challenge. In the Northeast U.S., State level Index of Biotic Integrity ranks and datasets only exist in Pennsylvania and Maryland, and even these focus only on wadeable rivers. Although some water quality and biomonitoring data existed in various states, this information was not readily available or in a standardized comparable format across states. Viability thresholds for condition variables related to the biological functioning of aquatic ecosystems

[19] Moyle and Randal 1998

have also not been extensively researched and developed, with the exception of impervious surface thresholds. There was also limited time and funding to compile and analyze existing instream sample data and its relation to the intactness and functioning of aquatic ecosystems.

Given these challenges, a two phase approach was taken. First, available spatial data was used to perform a GIS condition screening analysis to rank all watersheds and individual stream segments according to landscape factors that previous research has shown are correlated with biological integrity of aquatic communities.[20] Second, this preliminary assessment was refined and expanded during a series of expert interviews conducted with scientists and resource managers across the planning region. Experts were asked to comment on the TNC aquatic classification, identify threats and local conditions that were not modeled in the GIS screening, and highlight location of best examples of high-quality aquatic sites in the ecoregion.

The GIS screening analysis was used as a surrogate, but standardized, method of evaluating current condition of the aquatic ecosystems. It used landscape variables such as percent developed land, road density, density of road/stream crossings, percent agriculture, dam density, dam storage capacity, drinking water supply density, and point source density. These variables were divided into three generally non-correlated impact categories 1) Land cover and Road Impact to represent changes in permeable surfaces and other threats from roads, urbanization, or agriculture; 2) Dam and Drinking Water Supply Impacts to represent changes in hydrologic regime and migration barriers from dams; and 3) Point Source Impact to represent potential point source chemical alteration threats.

Ordinations were run on a subset of variables in the Land cover and Road Impact, Dam and Drinking Water Supply Impact, and Point Source Impact categories to develop a rank for each size 2 watershed in each impact category. The ordination ranks were used to highlight the most intact watershed examples within each watershed system type. Three variables, percent developed land, percent agriculture land, and total road density per watershed area, were also used to develop a simplified overall "landscape context" rank for each size 2 watershed. See Table 3 for the landscape context component rank criteria. The overall Landscape Context watershed rank was determined by worst individual component category score.[21]

Table 3: Watershed Landscape Context Ranking

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%		

At the aquatic expert interviews, experts at the state level were engaged for information on local conditions that could not be modeled in a GIS such as stocking, channelization, introduced

[20] Fitzhugh 2000
[21] For more information on the reach and watershed level condition variables and statistical ranking analysis, see Olivero 2003.

species, dam operation management techniques, and local water withdrawal. TNC field offices hosted a series of expert workshops to engage aquatic experts with land or resource management agencies, academic institutions, private consulting firms, and/or non-profit organizations based in the region. At these meetings experts provided input on previous work conducted by TNC such as the aquatic classification, GIS condition screening, and conservation planning approach. Experts were also specifically asked to delineate areas of aquatic biological significance on maps and provide descriptions of these areas by filling out a description form (see Appendix 2) on each area of aquatic biological significance.

Assembling the Portfolio

A portfolio assembly meeting was held with one or two representatives from each of the TNC state offices in the ecoregion. Prior to this meeting, each state had prioritized Size 2, 3, and 4 Aquatic Ecological System examples within their state for each watershed system group. Each office ranked occurrences based on the GIS screening analysis and expert information, such as best example of an intact system, presence of rare species, presence of native fish community, presence of excellent stream invertebrates, great condition, or free from exotics.

At the portfolio assembly meeting, field office representatives discussed and compared examples of given system groups that crossed state boundaries to select examples for the portfolio. The team was asked to identify the Portfolio Type Code categories for selected examples (Table 4 and 5). The team also identified the regional connected focus networks that would be part of the plan.

A considerable amount of professional judgement was exercised in assembling the conservation portfolio. In relatively intact landscapes where there were many high quality examples of each Aquatic Ecological System type, we included more than one instance of each watershed system in the conservation portfolio. In these cases, priorities for conservation action may depend on opportunity and imminence of threat. Conversely, in some degraded landscapes, there were few or no high quality examples of certain system types. In these areas, we recognize that restoration may be necessary to elevate the condition of systems included in the portfolio.

Table 4: Portfolio Type Code

PORT-S1c	Best available example of a stream/river system type and part of a regional or intermediate scale connected stream network
PORT-S1	Best available example of a stream/river system type but disjunct/not part of a focus connected stream network
PORT-S2c	Additional good example of a stream/river system type and part of a regional or intermediate scale focus connected stream network, but not the best example of its system type
PORT-S2	Additional good example of a stream/river system (often included the headwaters in all matrix sites) but disjunct from larger focus connected network
PORT-Sxc	Connector. Not an excellent or additional good best example of a stream/river system. It is considered as part of the portfolio as a connector segment in a focus connected stream network. These connectors usually are the lower mainstem reaches in a focus network that are highly altered but needed for connectivity. This connector occurrence is necessary to meet regional connectivity needs

Table 5: Confidence Code

1	High Confidence. We have high confidence that these expert recommended systems are both important and viable as aquatic conservation targets. Confidence 1 AESs often fall within the optimal condition analysis (% natural cover, road density, dams) as well.
2	Lower Confidence. These occurrences are only *conditionally* in the portfolio. Confidence 2 occurrences require more evaluation before we would take conservation action at these sites. They appear to be good aquatic conservation areas and appear to be necessary additions to the portfolio, but we need more information on these sites.

AQUATICS APPENDIX 0

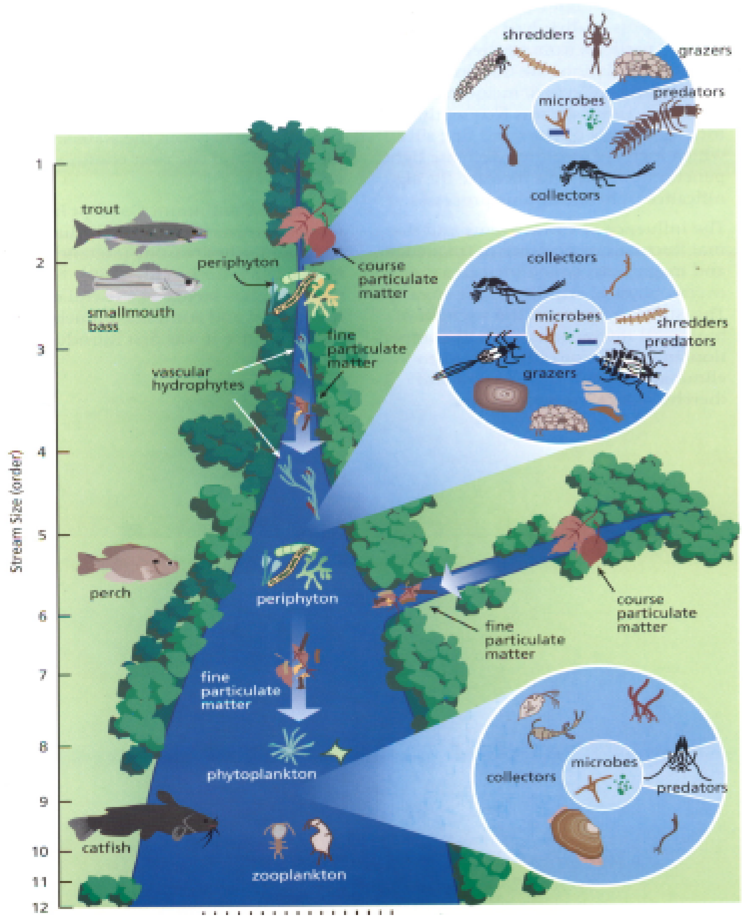

Figure 1: River Continuum in Size

AQUATICS APPENDIX 1

Proposed Aquatic Biota Relationship to Upper Connecticut and Middle Connecticut Ecological Drainage Units Aquatic Classification Units. Based primarily on Vermont Community Classification (Langdon et al 1998, St. Lawrence Ecoregional Aquatics Classification (Hunt 2002), and New York Community Classification (Reschke 1990). Compiled by Mark Anderson 3/2001.

TYPE	CHARACTERISTICS	ELU signature
SIZE 1 STREAM NETWORKS	**Riffles (50%) Pools (50%) Occur on all elevation/slope classes Cool – cold water, Headward erosion, Minimal deposition, Leaf shredders dominant**	**Size 1 Watershed, 0-30 sq. mi.**
A: SIZE 1, HIGH GRADIENT	Cold water over eroded bedrock, Energy source is terrestrial leaf litter, Shaded with 75-100% canopy cover, Mosses and Algae, few rooted plants. Substrate is boulder cobble gravel	Watershed dominated by slopes > 2% . Features: Sideslopes, steep slopes, cliffs, coves, gentle slopes
SIZE 1, HIGH GRADIENT, ACIDIC BEDROCK Plants: acid tolerant bryophytes, non vegetated areas Macroinverts: acid tolerant leaf shredders, low species diversity: Caddisflies (*Parapsyche, Palegapetus*)-Stoneflies (*Capniidae*)-Non-biting midges (*Eukiefferella*), Mayflies (*Eurylophella*).Other preferential taxa Caddisflies?(*Symphitpsyche*), Stoneflies (*Leuctridae, Taenionema, Chloroperlidae, Peltoperla*), Water strider (pools). Possible taxa Alder flies, Beetles (*Psephenidae*), Mollusca (*Elliptio*), Mayflies (*Heptagenidae*).		Watershed composed primarily of acidic bedrock types
	MID to HIGH ELEVATION: very cold, fast moving water, typically found in northern hardwood or spruce fir setting. Fish: Brook trout	Watershed mostly above 1700 ‘ Conifers prominent
	LOW ELEVATION: cold fast moving water, typically found in Pine-hardwoods, Oak – pine, or Oak –hardwoods setting. Fish: Brook trout, Slimy sculpin, Blacknose dace	Watershed mostly within the 800-1700’ elevation zone, Deciduous or Mixed.
	VERY LOW ELEVATION: cool fast moving streams, typically found in Oak-ericad, Oak hickory, Pine – Oak settings. Fish: Brook trout, Slimy sculpin, Blacknose dace, others?	Watershed mostly within the 0- 800’ elevation zone, Deciduous or Mixed
SIZE 1 HIGH GRADIENT CIRCUM-NEUTRAL BEDROCK Plants: circumneutral, *acid intolerant* bryophytes, non vegetated areas Macroinverts: circumneutral , *acid intolerant* leaf shredders: Mayflies (*Rithrogenia*)-Caddisflies (*Symphitopsyche?, Glossosoma*)-Flies (*Simulium, Antocha*) Stoneflies (*Peltoperla, Chloroperlidae, Malikrekus, Capniidae, Agnetina*), Beetles (*Oulimnius, Optioservus, Ectopria*), Non-biting midges (*Crictopus, Polypedilum*), Mayflies (*Ephemerella, Serratella*), Flies (*Hexatoma*), water striders (pools)		Watershed composed primarily of calcareous bedrock types
	MID to HIGH ELEVATION: very cold, fast moving water, typically found in northern hardwood or spruce fir setting. Fish: Brook trout	Watershed mostly above 1700 ‘ Conifers prominent
	LOW ELEVATION: cold fast moving water, typically found in Pine-hardwoods, Oak – pine, or Oak –hardwoods setting. Fish: Brook trout, Slimy sculpin, Blacknose dace	Watershed mostly within the 800-1700’ elevation zone, Deciduous or Mixed.
	VERY LOW ELEVATION: cool fast moving streams, typically found in Oak-ericad, Oak hickory, Pine – Oak settings Fish: Brook trout, Slimy sculpin, Blacknose dace, others?	Watershed mostly within the 0- 800’ elevation zone, Deciduous or Mixed
B: SIZE 1, LOW GRADIENT (MARSHY) STREAMS	Cool to cold water small brook that flows through a flat marsh, fen, swamp or other wetland. Energy source is leaf litter, may be open or shaded. Substrate is clay-silt-sand dominated, Sand >silt/clay, cold, usu associated with springs, Complete canopy cover of dense veg, alder, willows, dogwood, cedar, marsh veg:	Watershed dominated by flats < 0-2 % Slopes Features: wet flats, valley bottoms, dry flats, marshes and bogs
SIZE 1, LOW GRADIENT, ACIDIC BEDROCK Plants Potamogeton sp, Brasenia schreberii, Vallisneria sp, Myriophylum sp Macroinvert Indicators: Mollusca (*Pisidium*)-Caddisflies (*Polycentropus*)-Mayflies (*Litobrancha*)-Dragon/damselflies (*Cordulegaster*)		Watershed composed primarily of acidic bedrock types
	MID to HIGH ELEVATION: very cold, fast moving water, typically found in northern hardwood or spruce fir setting. Fish: Brook trout	Watershed mostly above 1700 ‘ Conifers prominent
	LOW ELEVATION: cold fast moving water, typically found in Pine-hardwoods, Oak – pine, or Oak –hardwoods setting. Fish: Brook trout, Slimy sculpin, Blacknose dace	Watershed mostly within the 800-1700’ elevation zone, Deciduous or Mixed.
	VERY LOW ELEVATION: cool fast moving streams, typically found in Oak-ericad, Oak hickory, Pine – Oak settings. Fish: Brook trout, Slimy sculpin, Blacknose dace, others?	Watershed mostly within the 0- 800’ elevation zone, Deciduous or Mixed
SIZE 1, LOW GRADIENT , CIRCUMNEUTRAL BEDROCK Plants: Potamageton spp, Elodia, Nymphaea		Calc bedrock Slope 0-2%

Macroinverts: Flies (*Tipula, Atherix, Simulum*)-Non-biting midges (*Apsectrotnypus, Rheocricotopus*)-Crustacae (*Hyallela*)-Mollusca (*Pisidium*)-Mayflies (*Stenonema*) (Vt type 7 (very low, in Champlain valley))		
MID to HIGH ELEVATION: very cold, fast moving water, typically found in northern hardwood or spruce fir setting. Fish: Brook trout		Watershed mostly above 1700 ‘ Conifers prominent
LOW ELEVATION: cold fast moving water, typically found in Pine-hardwoods, Oak – pine, or Oak –hardwoods setting. Fish: Brook trout, Slimy sculpin, Blacknose dace		Watershed mostly within the 800-1700’ elevation zone, Deciduous or Mixed.
VERY LOW ELEVATION: cool fast moving streams, typically found in Oak-ericad, Oak hickory, Pine – Oak settings. Fish: Brook trout, Slimy sculpin, Blacknose dace, others?		Watershed mostly within the 0- 800’ elevation zone, Deciduous or Mixed
SIZE 2 MIDREACH STREAM	**Riffles, Pools and Runs, Open or partial canopy, Algal shredders/scrapers usually well represented, low to very low elevations only. Generally slightly alkaline**	**Size 2 Watershed: 30-200 sq.mi.**
Sloping, confined channel, midreach stream in low mountains.	Riffles (33%), Runs (33%), Pools (33%) (VT macro type 3 and 4) Average 35%-45% canopy, Typically in mountainous areas Plants: emergents, macrophytes, algae and bryophytes Macroinvertebrates: Algae shredders and scrapers: (Vt type 3) mt areas: Stoneflies (*Chloroperlidae*)-Caddisflies (*Dolophilodes, Rhychophila*)-Flies (*Hexatoma*)-Beetles (*Oulimnius*) Generally poor mussel diversity, with acid tolerant species. Other preferential Taxa: Caddisflies (*Brachycentrus, Lepidostoma, Apatania, Symphitopsyche?, Polycentropus*), Beetles (*Promoresia, Optioservus*), Non-biting midges (*Eukiefferella, Tvetenia, Parachaetocladius, Micropsectra, Microtendipes, Polypedilum*), Mayflies (*Epeorus, Rhithrogena*), Dragon/damseflies (*Gomphidae*), Stoneflies (*Capniidae, Peltoperla, Leuctridae, Agnetina, Isogenoides*). Fish: Brook trout, Blacknose dace, Longnose dace, Creek chub, Longnose sucker, White sucker,	Slope >2 Or stream on slope-bottom flat Elev 800-1700’
Sloping, confined channel, midreach stream in very low valleys.	Riffles (33%), Runs (33%), Pools (33%) (VT macro type 3 and 4) Average 35%-45% canopy, Typically in lower reaches of small rivers, gen in lower valleys of major watersheds, Plants:emergents, macrophytes, alge and bryophytes. Macroinverts: (Vt type 4 lower valleys) Stoneflies (*Chloroperlidae*)-Caddisflies (Dolophilodes, Rhychophila)-Flies (*Hexatoma*)-Beetles (*Oulimnius*) Mayflies (*Isonychia*), Non-biting midges (*Polypedilum*), Beetles (*Dubiraphia, Promoresia*). Other possible taxa: Beetles (*Psephenidae*), Alder flies (*Corydalidae*), Dragon/damseflies (good diversity; *Calyopterygidae*), Mollusca (Elliptio, Pyganodon, Sphaerium, questionably Margaritifera), Mayflies (Ephemeridae), Crustacea (Cambaridae) (green stoneflies (Chloroperlidae), Dolophilodes, Hexatoma, Rhychophila, Oulimnius). Poor NYHP understanding of assemblage. (Promoresia, Neoperla, Chimarra, Stenelmis) Fish: transitional cold/warm species: Blacknose dace, Longnose dace, White sucker, Creek chub, Flathead minnow, Bluntnose minnow	Slope >2 Or stream on slope-bottom flat Elev 0-800’
Flat meandering midreach stream	Runs (50%), Pools (50%) (VT macrotype 6) Average 35% canopy, broader valleys with low slopes of large drainage areas Plants: Alders, willow along banks, Floodplain forest and other rivershore communities Macroinvertebrates: Beetles (*Dubiraphia*)-Non-biting midges (*Polypedilum*)-Mayflies (*Leptophelbidae*)-Mollusca (*Pisidium*)-Odonota (*Aeshinidae*) Broad winged damselflies *Calopterygidae*, Narrow winged damselflies *Coenagrionidae*, Clubtails	Slope 0-2% (wetflats) and not a slope bottom flat

			Gomphidae)-Caddisflies (*Hydaphylax, Dubiraphia, Polypedilum)* Fish, warmwater species, coldwater absent: Bluntnose minnow, Creek chub, Blacknose dace, Tessellated darter, White sucker.	
		Midreach stream entering large lakes	Need more information, Mollusca (*Potamilus, Lampsilis, Leptodea, Pyganodon, Sphaerium, Pisidium*)-Mayflies (*Hexagenia*)-Beetles (*Dubiraphia*)-Caddisflies (*Phylocentropus*)-Crustacea (*Gammarus*)-Non-biting midges (*Polypedilum*)-Flies (*Spheromias, Culicoides*) Fish 80 + warmwater species in Lake Champlain region	Under 150' elev???
LARGE, SIZE and SIZE 4 RIVERS				**Size 3: 200-1000 sq.mi.; Size 4: > 1000 sq.mi.+**
		Large main channel river	Each river and drainage basin should be treated separately Fish include American shad, Atlantic salmon, and other warmwater species	
SPECIAL SITUATIONS			Small patch situation that may not be predictable but are usually associated with one or several of the main types. For example backwater sloughs are primarily associated with 3-5 order meandering streams.	
			1: Seeps (treated through palustrine veg class)	
			2: Backwater slough (associated with 3-5 order meandering streams)	
			3: Lake outlet and inlet streams (need clarity from lake classification)	
			4: Subterranean stream (associated with limestone bedrock, EOs present)	
			5: Intermittent stream (associated with 1^{st} order streams)	

AQUATICS APPENDIX 2

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

Specific Information on Nominated Areas of Aquatic Biological Significance

Expert Name(s):

____

Site Code:

____

(Please write your initials, date of description (mmddyy), and sequential letter for sites you describe). For example: **GS020802A** = (George Schuler - Feb. 8, 2002 – first site described)

Site Name:

____

Describe any current Conservation Work being done at this site:

____

____

Who is/are the lead contact person(s) for additional information about this site?

Name ______________________________

Agency/Address____________________________________

Email _________________________ Phone

____

Name ______________________________

Agency/Address____________________________________

Email _________________________ Phone

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Biological description (e.g., native species assemblages, indicator or target species, unique biological features, important physical habitat, etc.):

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____

Key Ecological Processes: (e.g., the dominant disturbance processes that influence the site such as seasonal flooding or drought, ice scouring, groundwater recharge, seasonal precipitation events, etc.)

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____

Major stresses: Using the following list, rank the major stresses at this site:

Habitat destruction or conversion

B. Habitat fragmentation

C. Habitat disturbance

D. Altered biological composition/structure

E. Nutrient loading

F. Sedimentation

G. Extraordinary predation/parasitism/disease

H. Modification of water levels; changes in flow

I. Thermal alteration

J. Groundwater depletion

K. Resource depletion

L. Extraordinary competition for resources

M. Toxins/contaminants

N. Exotic species/invasives

O. Other: ______________________________

Major sources of stress: Using the following list, circle up to 3 sources of stress at this site:

A. **Agricultural** (Incompatible crop production, livestock, or grazing practices)
B. **Forestry** (Incompatible forestry practices)
C. **Land Development** (Incompatible development)
D. **Water Management** (Dams, ditches, dikes, drainage or diversion systems, Channelization, Excessive groundwater withdrawal, Shoreline stabilization)
E. **Point Source Pollution** (Industrial discharge, Livestock feedlot, Incompatible wastewater treatment, Marina development, Landfill construction or operation)
F. **Resource Extraction** (Incompatible mining practices, Overfishing)
G. **Recreation** (Incompatible recreational use, Recreational vehicles)
H. **Land/Resource Management** (Incompatible management of/for certain species)
I. **Biological** (Parasites/pathogens, Invasive/alien species)
J. **Other:**

____

Further description of stresses or sources of stress:

____

____

TNC RANKING - Site Description:

Describe each site according to each of the three components of viability below (i.e., size, condition, landscape context). Once described, attach a status rating (i.e., Very Good,

Good, Fair, Poor) for each of the three components and provide written justification for your assessment.

Size: (e.g., describe the species and specific life history stages (if known) that use the site and any information about specific life history stages):

Condition: (e.g., describe aspects of biotic composition, local anthropogenic impacts, degree of invasive species, etc.):

Landscape (Waterscape?) Context: (e.g., describe the altered flow regime, connectivity with other aquatic habitats, watershed impacts, unique or notable physical features, landscape setting, etc):

Additional Comments not captured by this survey: