# State of New Hampshire

Inter-Department Communication

**Date**: March 9, 2006

**From**: Phil Trowbridge
David Neils

**At** (Office): Environmental Services
Watershed Management

**Subject**: Probabilistic Assessments of Wadeable Streams for the 2006 305(b) Report

**To**: Gregg Comstock, Supervisor, Water Quality Planning Section

## Introduction

The purpose of this memorandum is to summarize the results of probabilistic assessments of designated uses in wadeable streams for New Hampshire's 2006 305(b) Report. Probability based monitoring uses randomly assigned stations to take an unbiased sample of a natural resource. Statistics from the sample can be used to make inferences about conditions throughout the resource. The major advantage of this approach is that 100% of the resource can be assessed at minimal cost. The biggest disadvantage is that the specific locations of water quality violations cannot be inferred from the statistical sample. Therefore, the results of the probabilistic assessment must be used in concert with the deterministic assessments of individual assessment units in the DES Assessment Database.

## Methods

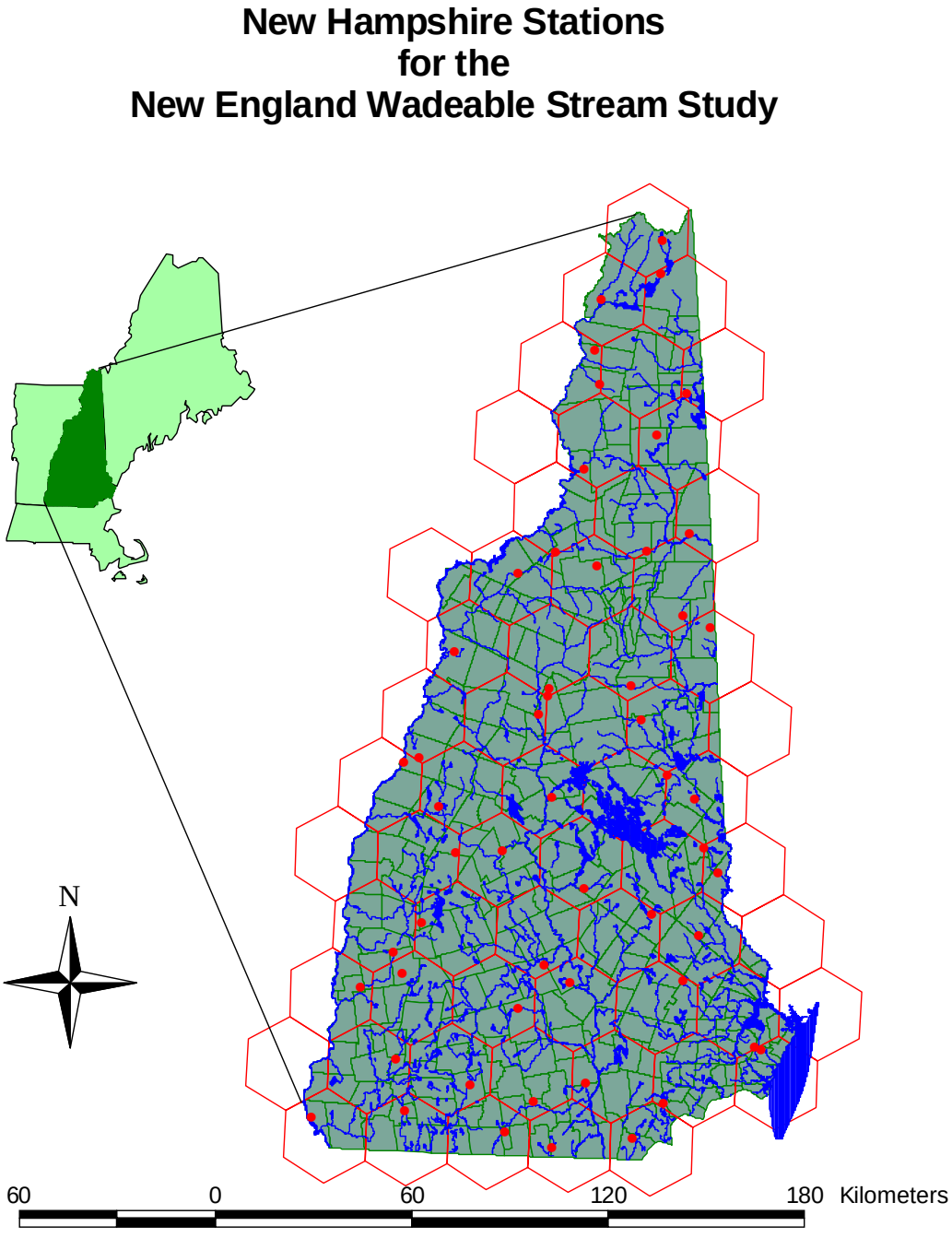
### *Data Source*

Data for the aquatic life use support portion of these assessments were collected for the New England Wadeable Streams (NEWS) Study. The New England Wadeable Stream Study was a regional monitoring effort organized by the U.S. Environmental Protection Agency Region I and completed by DES. The study involved the collection of physical, chemical, and biological data at a set of probabilistic stations in 2002 and 2003. In 2005, the DES Ambient River Monitoring Program returned to the NEWS sites and measured bacteria indicators in order to assess primary and secondary contact recreation.

### *Study Area*

The study area was all of the wadeable streams in New Hampshire (Figure 1). Wadeable streams are assumed to be streams of first through fourth order. The DES Assessment Database indexes 9,628 stream miles of river assessment units. These river assessment units were created from the 1:100,000 National Hydrography Dataset after removing "transfer reaches" which pass through lakes, impoundments and estuaries. The National Hydrography Dataset did not contain stream order as an attribute for the river segments. However, DES used a 1:24,000 coverage of stream order to estimate that only 6% of the stream miles in New Hampshire are fifth order or higher. Assuming that the fraction of higher order streams at the 1:24,000 scale is the same as for the 1:100,000 scale, the total number of river miles of first through fourth order should be 94% of 9,628 or 9,050 miles.

**Figure 1**


New Hampshire Stations
for the
New England Wadeable Stream Study
N
60
0
60
120
180
Kilometers

*Statistical Methods*

EPA cartographers overlaid the entire State with a hexagonal grid consisting of 61 equal area hexagons (Figure 1). ArcInfo software was used to randomly assign sampling stations in the resource inside each hexagon. Each of the hexagons was assigned a weighting factor which was the ratio of the river miles inside the hexagon to the total river miles in the state. DES calculated the river miles for the hexagons using the river assessment units in the DES Assessment Database. It was assumed that the small proportion of stream miles for fifth order and higher streams would not affect the weighting factors significantly. For two hexagons (hex id 4 and 30), there were two stations in the same hexagon. For these cases, the weighting factor for the hexagon was split equally between the two stations.

The data from each station was evaluated and classified into categories for each designated use using the Consolidated Assessment and Listing Methodology (DES, 2006). The proportion of the resource with each category was calculated by summing the weighting factors for all the hexagons with the same category. The uncertainty in the proportions was estimated using the equation for variance in a binomial proportion based on the sample size and assuming equal station weights. A $95^{th}$ percentile precision was used for confidence limit calculations.

The results for each designated use were presented as both the percent of the resource and the number of stream miles in each category.

*Environmental Indicators*

Three designated uses for wadeable streams were assessed using data collected at the NEWS stations: Aquatic life use support, primary contact recreation, and secondary contact recreation. The core indicator for aquatic life use support was a biological assessment based on benthic macroinvertebrates. For primary and secondary contact recreation, the core indicator was *Escherichia coli*. These indicators were evaluated at each of the stations to determine whether the station should be classified as Fully Supporting, Insufficient Information, or Not Supporting.

For aquatic life use support, the DES Biomonitoring Program assessed benthic macroinvertebrate data using a modified index of biological integrity (IBI). Placement of sites into aquatic life use support categories using macroinvertebrates was completed utilizing an assessment tool that differed from standard techniques outlined in the DES Consolidated Assessment and Listing Methodology (CALM; DES, 2006). Deviation from DES' wadable stream aquatic life use assessment tool as detailed in the CALM was necessary because macroinvertebrate samples collected using the NEWS field protocols differed dramatically from standard DES field techniques. The modified IBI consisted of 6 metrics (EPT taxa richness, % EPT taxa, Scraper taxa richness, % Clinger taxa, % intolerant taxa, % Individuals in top 5 taxa). The selection of IBI metrics was consistent with an IBI constructed for the northeastern United States as part of the ongoing National Wadable Stream Assessment (WSA) Project being completed by the US EPA and cooperating states. The metrics contained in WSA IBI were applied to the NEWS macroinvertebrate data because both projects utilized similar field collection protocols. The WSA IBI was subsequently recalibrated using regional reference sites from Maine, New Hampshire, and Vermont (northern New England, NNE). A total of 40 reference sites were selected as a subset of the WSA NNE reference sites. The threshold for Fully Supporting or Not Supporting aquatic life use categories was set at 68 out of a possible score of 100. Sites scoring less than 68 were considered Not Supporting while sites scoring 68 or greater were considered Fully Supporting. The aquatic life use reference threshold for the IBI was defined as the $25^{th}$ percentile of all reference site IBI scores. Following calibration, IBI scores were computed for

individual NEWS sites that were judged to be within either medium or high gradient streams. Low gradient streams for which biomonitoring data were collected were classified as Insufficient Information. The exclusion of low gradient streams from the probabilistic assessment differs from targeted wadeable stream aquatic life use assessments covered under the current DES CALM, but is consistent with the use and recalibration of WSA IBI. DES felt it was more important to be consistent with concurrent probabilistic data collection protocols and assessment indices than the assessment techniques developed specific to DES data collection protocols.

For demonstration purposes, the Biocondition Gradient (BCG) model developed by EPA was implemented for macroinvertebrate data collected from wadable streams. The model consists of 6 tiers that incorporate several community ecological attributes across increasing levels of human disturbance [(USEPA 2005) (See Appendix B for Tier description)]. The BCG model allows for the placement of sites into a tier based on community composition and abundance of specific taxa or ecological groups. The development of the BCG model was instigated by a recognized need for a common tool in communicating the condition of ecological communities. Unlike traditional IBIs, which generally support a single endpoint (i.e. above or below an established threshold), the BCG model provides multiple possible endpoints that are not strictly based on "use-support" thresholds and can be used to set management goals.

As part of the NEWS project, US EPA Region 1 and state cooperators worked in conjunction with a private contractor (Jeroen Gerritsen, Tetra Tech, Inc.) to develop an objective tool to place individual sites into a BCG tier. The state's role was to provide input on the biological and ecological attributes of individual or groups of macroinvertebrate taxa and the decisions used to place sites into BCG tiers. The private contractor then took this information and constructed an objective non-linear, logic based (Fuzzy Set) model that predicted the BCG tier. The model was calibrated from regional reference and test sites (N=43), then applied to the remaining regional NEWS sites to predict each site's BCG tier assignment. As noted above the results given herein are presented solely for demonstration purposes and not intended for regulatory interpretation[1].

For primary and secondary contact recreation, DES measured *E. coli* concentrations from three visits within a 60 day period at each of the stations. The assessment methods from the CALM could be used to assess attainment of the *E. coli* water quality standard without modification. Three of the NEWS stations fell within Class A waters. The *E. coli* standards for Class A waters were used to evaluate the data from the stations in Class A waters. Class B standards were used for the remainder of the stations.

**Results**

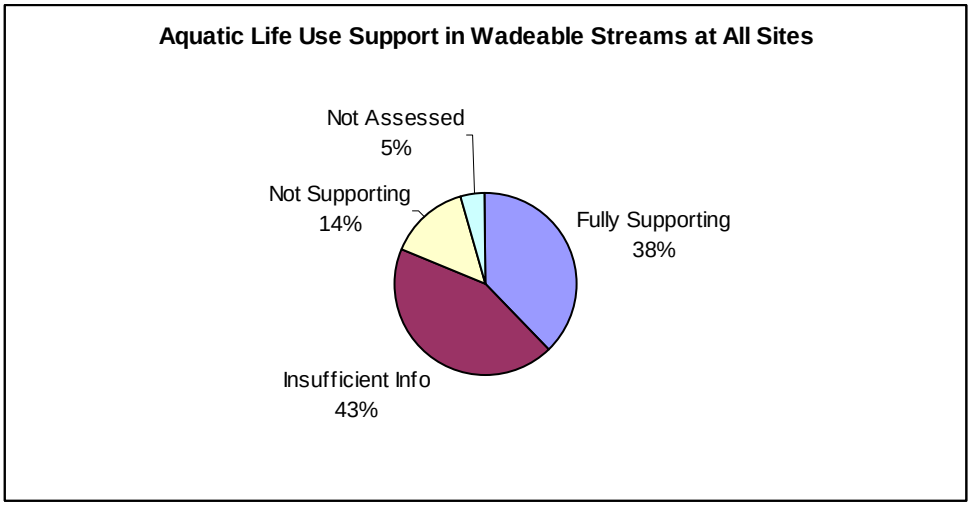
The results of the statistical analysis are shown in the following tables and figures. For each designated use, there is a series consisting of a summary table, two pie charts and a map of the state. For each series, the first chart shows the percent of wadeable streams in each category, including those streams that were not assessed. The second chart shows the percent of the resource in each category for only the monitored sites, which is equivalent to assuming that the stream miles that were not assessed have the same distribution of categories as the monitored sites. Two additional series of tables and charts demonstrate the BCG tier assignment via the fuzzy set model (Series 4) and correspondence with IBI assessment results (Series 5).

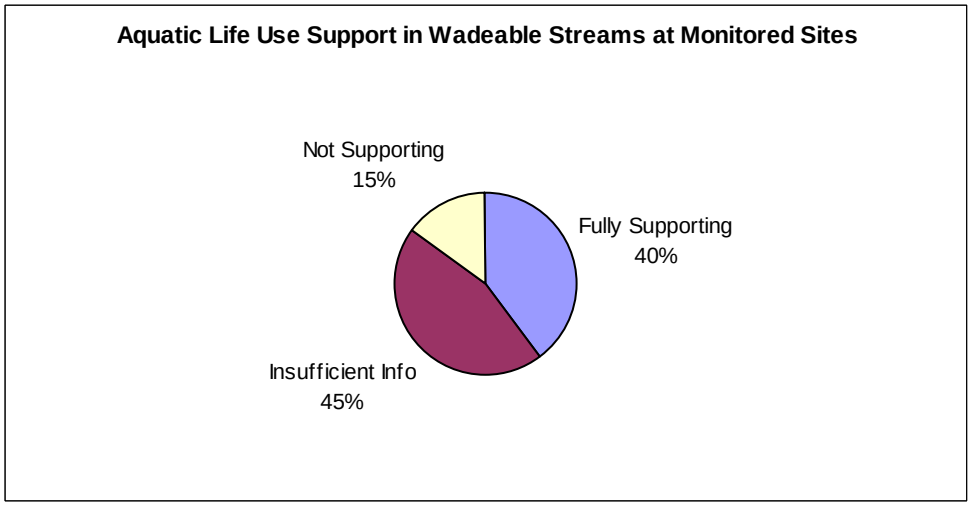
[1] BCG Fuzzy Set Model development, calibration, and application to the NEWS data is credited solely to Jeroen Gerritsen of Tetra Tech, Inc. The NH DES is responsible for the application of the results produced by the model and their incorporation into the probabilistic assessment of wadable streams in New Hampshire. Additional details about the BCG and the Fuzzy Set model will ultimately be available in future publications specific to the NEWS project.

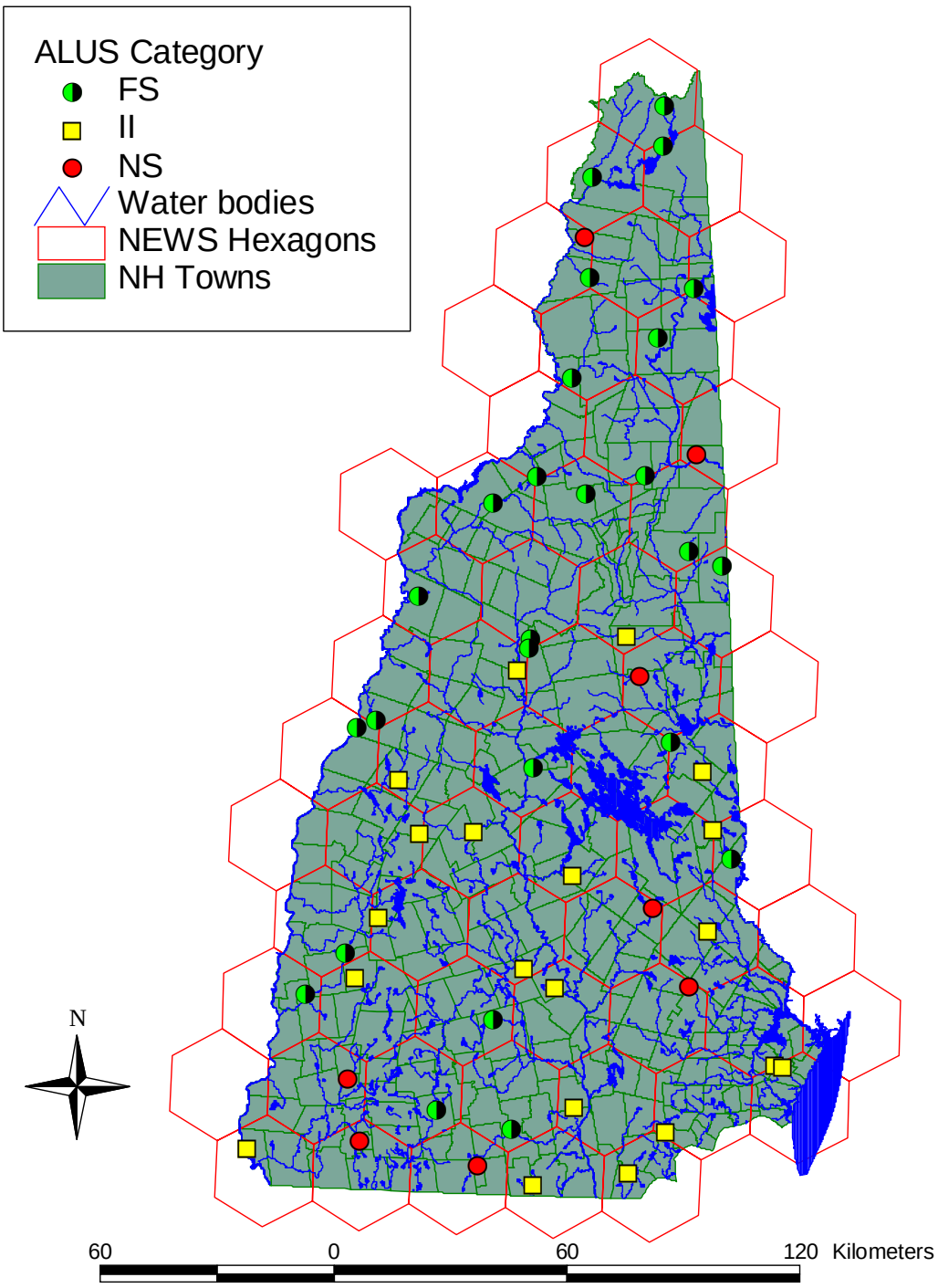
## Series 1: Aquatic Life Use

**Aquatic Life Use Support in Wadeable Streams**

| | Percent of Resource | | Stream Miles | |
|---|---|---|---|---|
| | Value | Error | Value | Error |
| Fully Supporting | 37.9% | 12.9% | 3,429 | 1,171 |
| Insufficient Info | 43.2% | 13.2% | 3,910 | 1,196 |
| Not Supporting | 14.3% | 9.3% | 1,298 | 846 |
| Not Assessed | 4.6% | | 413 | |
| Total | 100.0% | | 9,050 | |



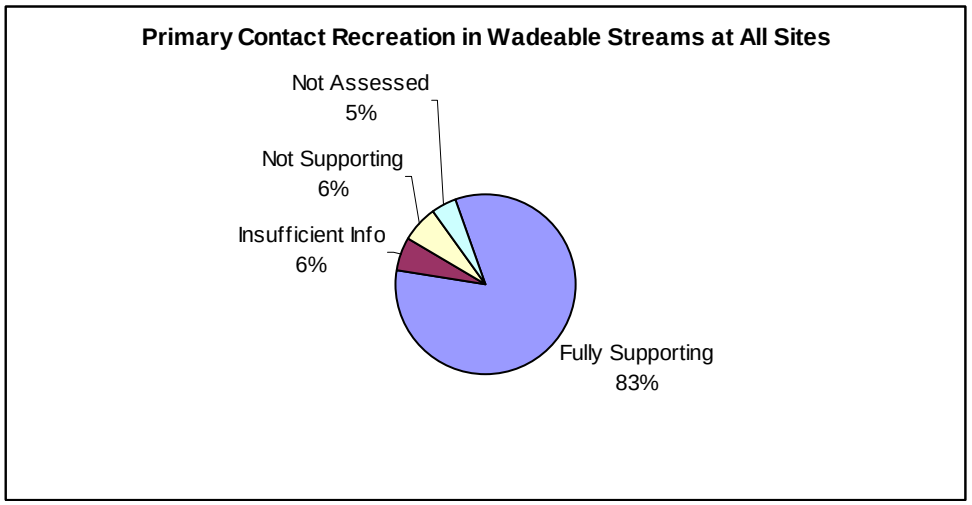



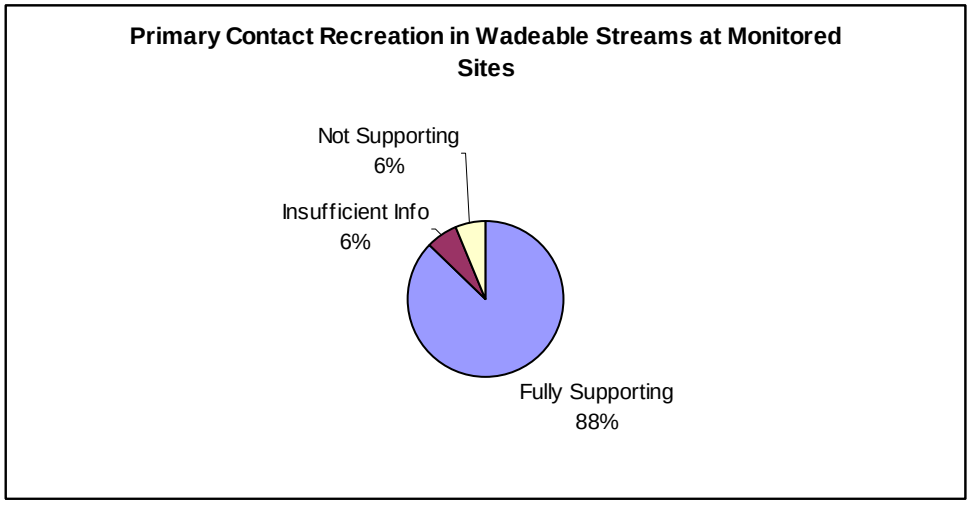

ALUS Category
FS
II
NS
Water bodies
NEWS Hexagons
NH Towns
N
60
0
60
120 Kilometers

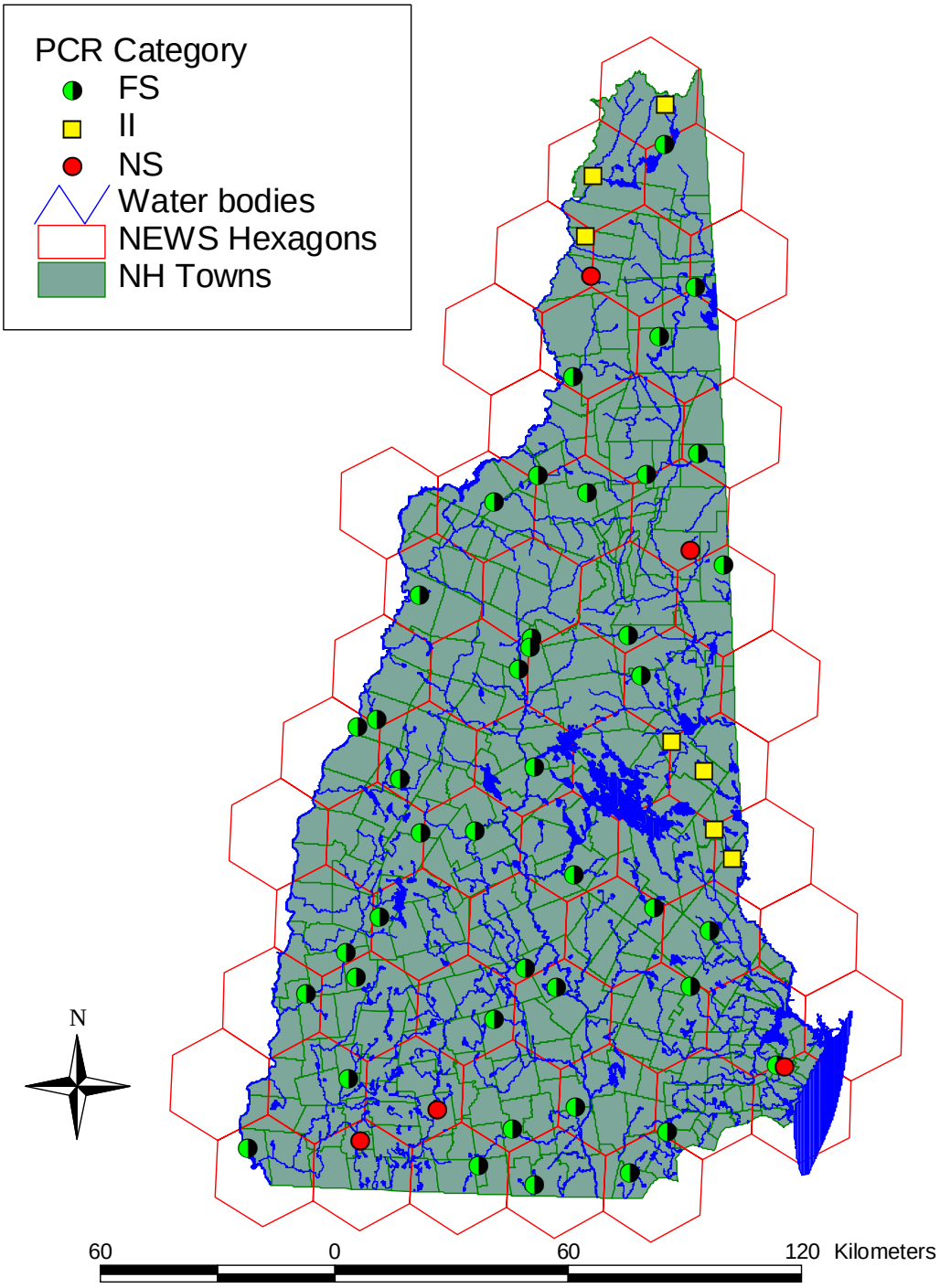
## Series 2: Primary Contact Recreation

**Primary Contact Recreation in Wadeable Streams**

| | Percent of Resource | | Stream Miles | |
|---|---|---|---|---|
| | Value | Error | Value | Error |
| Fully Supporting | 83.2% | 10.0% | 7,527 | 903 |
| Insufficient Info | 6.1% | 6.4% | 554 | 579 |
| Not Supporting | 6.1% | 6.4% | 556 | 579 |
| Not Assessed | 4.6% | | 413 | |
| Total | 100.0% | | 9,050 | |



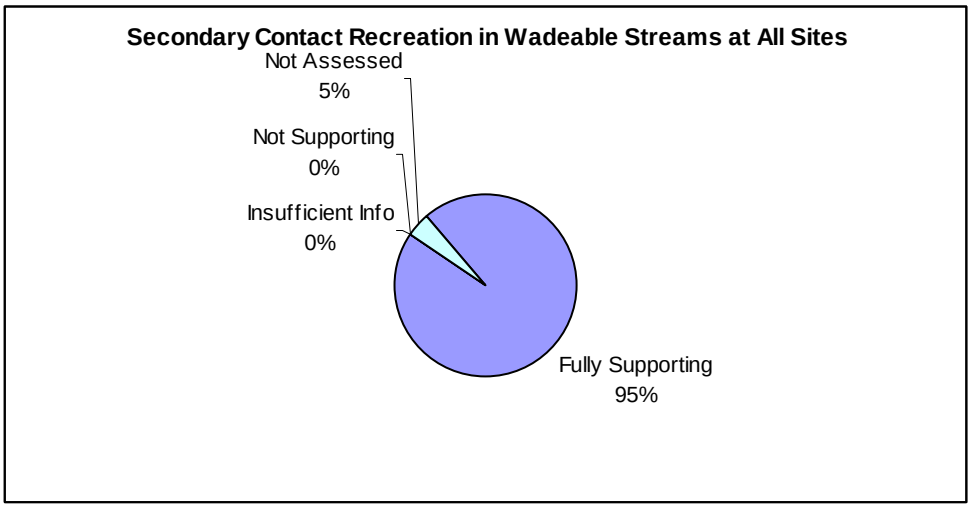



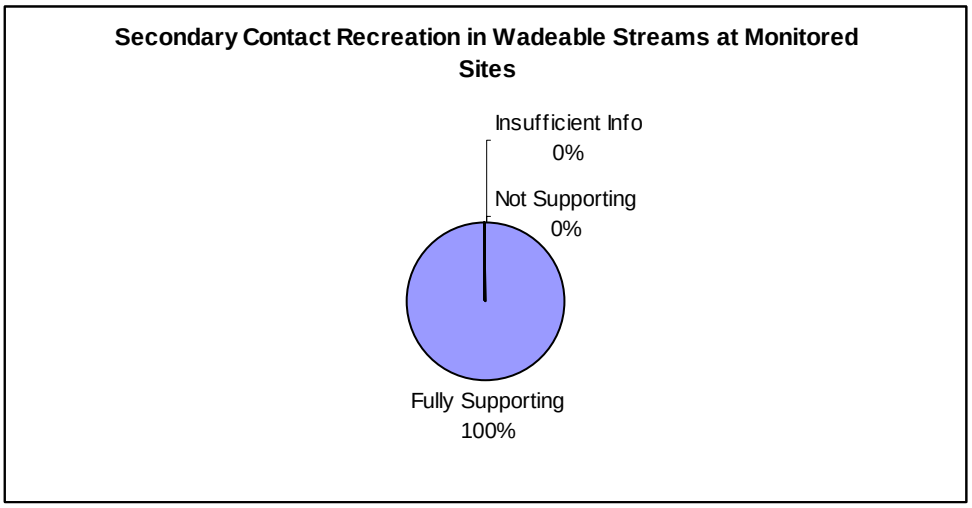

PCR Category
FS
II
NS
Water bodies
NEWS Hexagons
NH Towns
N
60
0
60
120 Kilometers

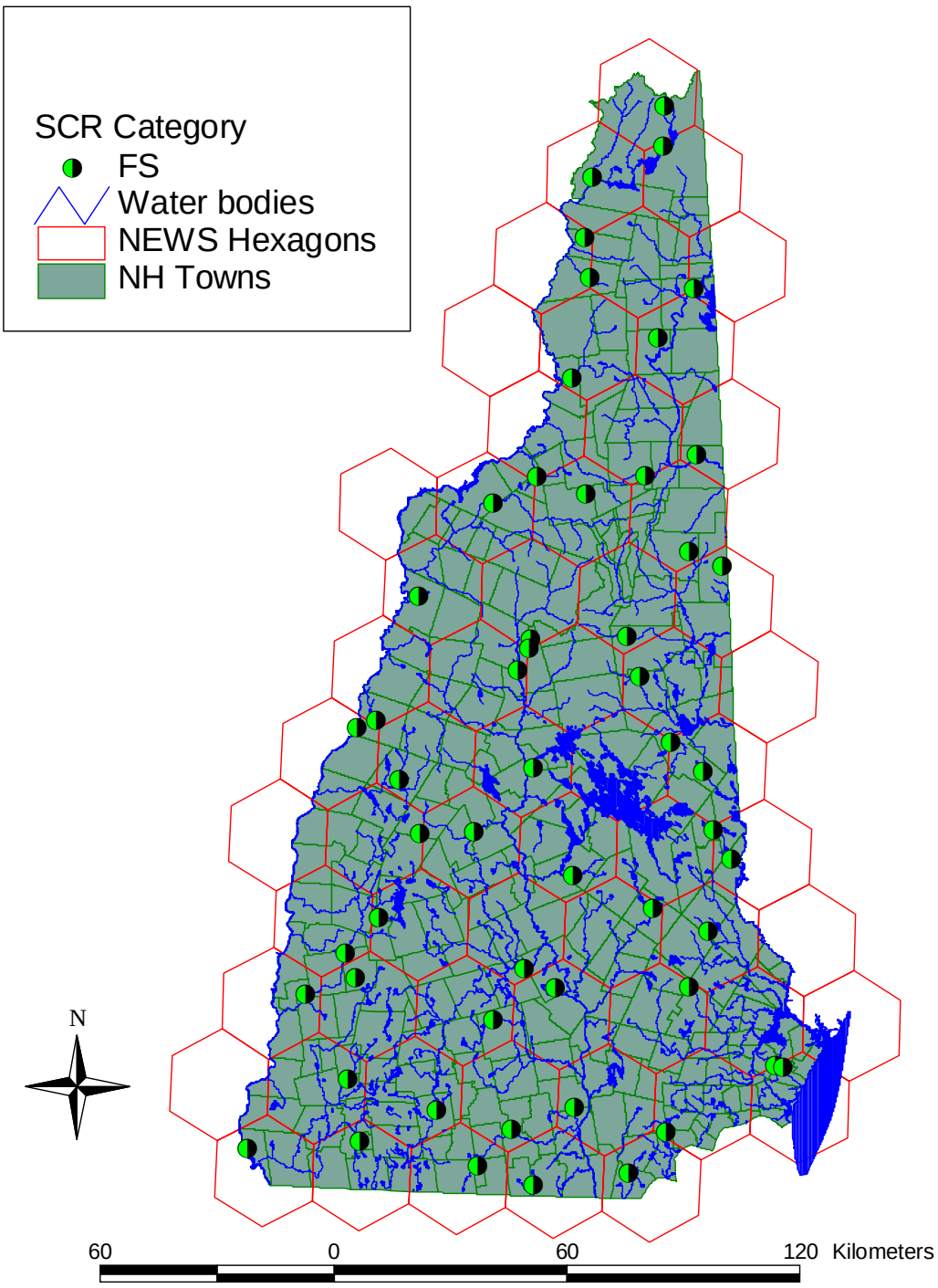
## Series 3: Secondary Contact Recreation

**Secondary Contact Recreation in Wadeable Streams**

| | Percent of Resource | | Stream Miles | |
|---|---|---|---|---|
| | Value | Error | Value | Error |
| Fully Supporting | 95.4% | 5.6% | 8,637 | 504 |
| Insufficient Info | 0.0% | 0.0% | 0 | 0 |
| Not Supporting | 0.0% | 0.0% | 0 | 0 |
| Not Assessed | 4.6% | | 413 | |
| Total | 100.0% | | 9,050 | |



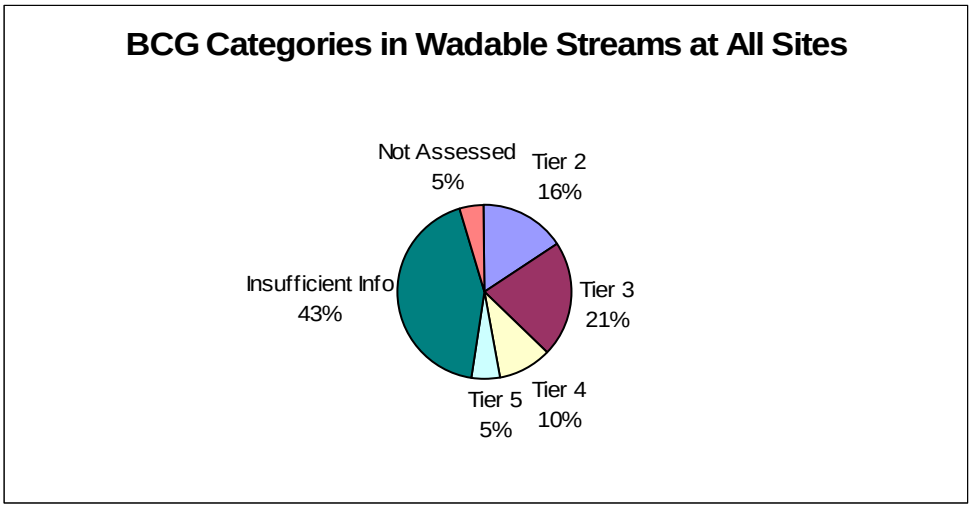



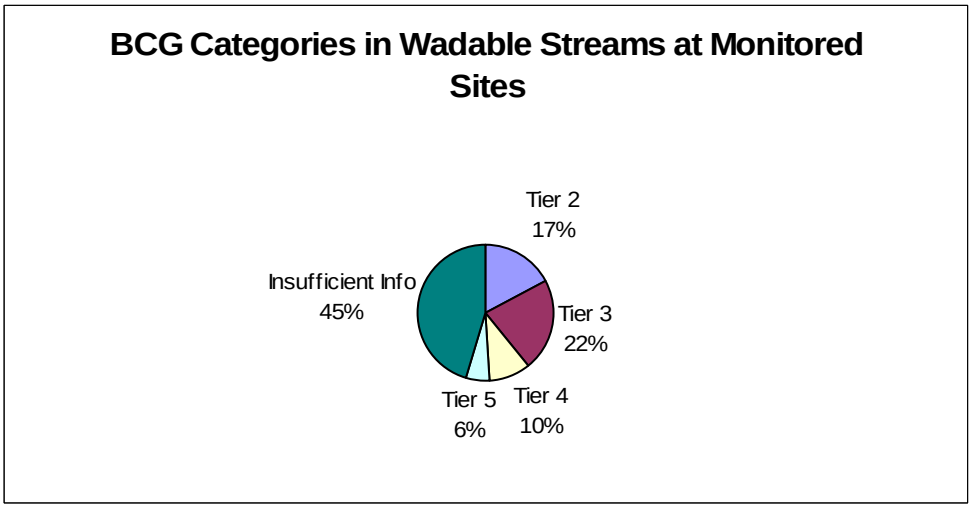

SCR Category
FS
Water bodies
NEWS Hexagons
NH Towns
N
60
0
60
120 Kilometers

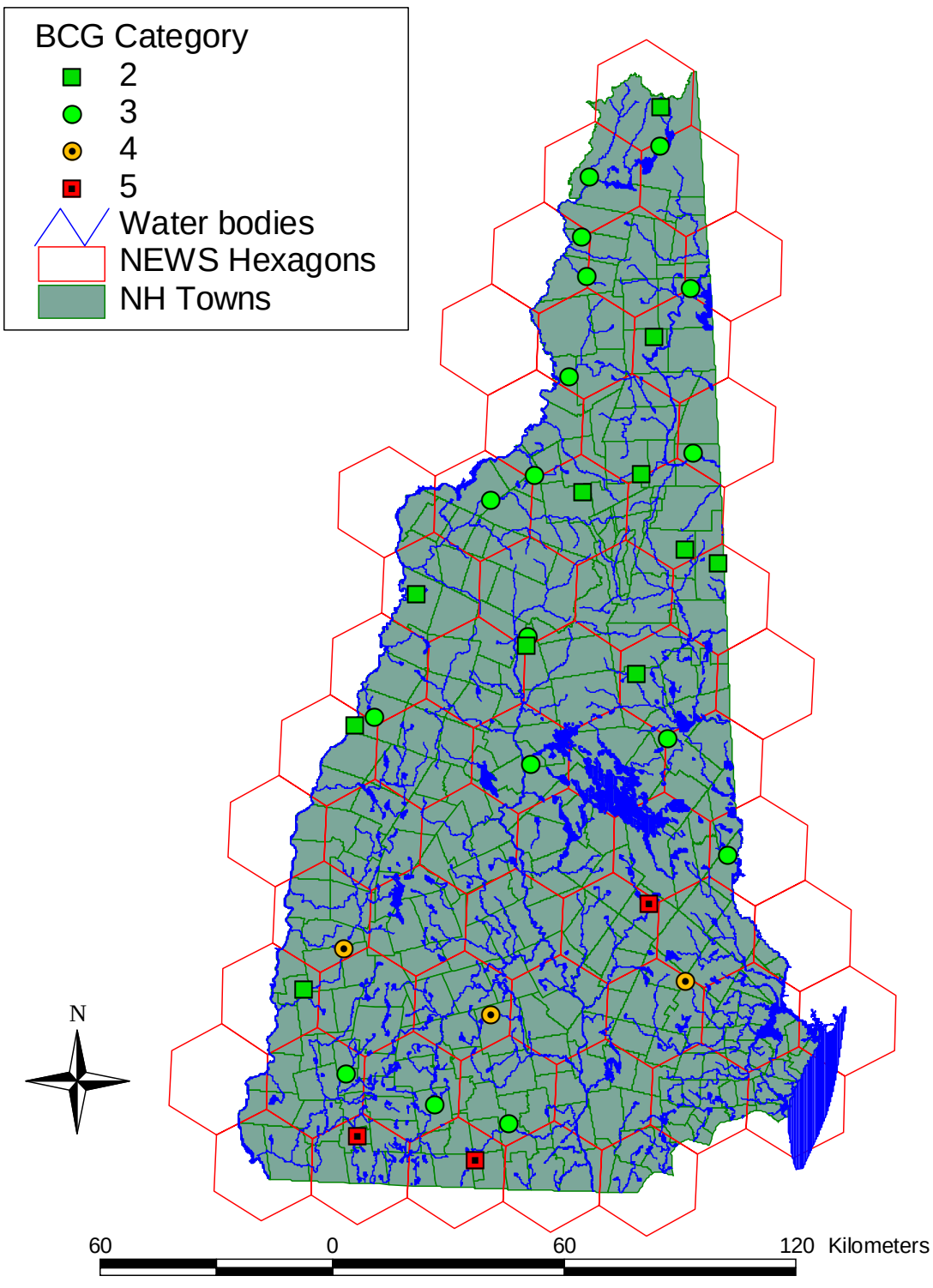
## Series 4: BCG Tiers

**BCG Categories in Wadable Streams**

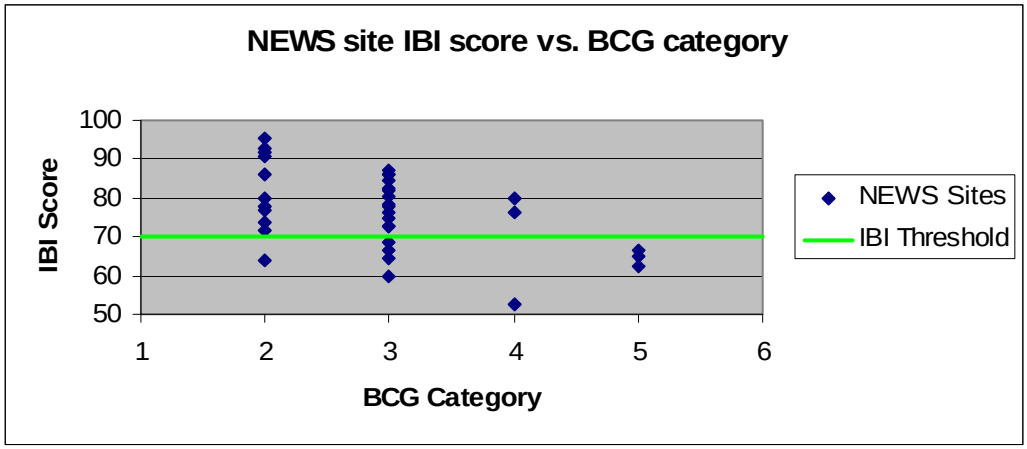
| | Percent of Resource | | Stream Miles | |
|---|---|---|---|---|
| Tier | Value | Error | Value | Error |
| Tier 2 | 16.1% | 9.8% | 1,457 | 887 |
| Tier 3 | 21.2% | 10.9% | 1,915 | 986 |
| Tier 4 | 9.7% | 7.9% | 877 | 714 |
| Tier 5 | 5.3% | 6.0% | 478 | 540 |
| Insufficient Info | 43.2% | 13.2% | 3,910 | 1,196 |
| Not Assessed | 4.6% | | 413 | |
| Total | 100.0% | | 9,050 | |

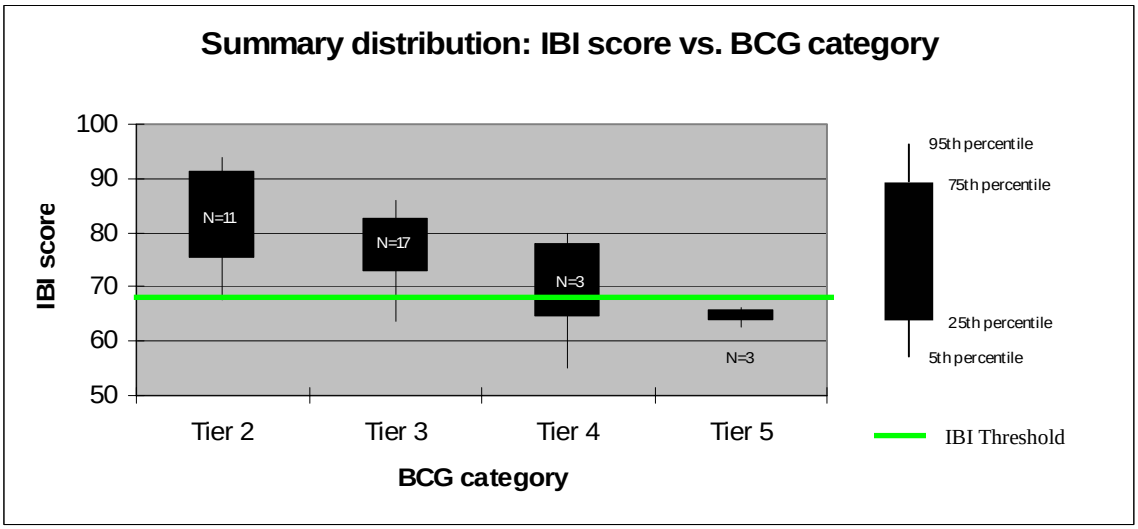



BCG Category
2
3
4
5
Water bodies
NEWS Hexagons
NH Towns
N
60
0
60
120 Kilometers

## Series 5. BCG Categories vs. IBI Scores



## Discussion

Data were available for the indicators for 95.4% of the wadeable stream miles. There was no information on the remaining 4.6% of the resource because the several hexagons in the original design were not sampled. The total miles of wadeable streams in New Hampshire was estimated to be 9,050. Therefore, these assessments cover 8,634 stream miles, which is 90% of the 9,628 stream miles for all the NHRIV assessment units.

For aquatic life use support, the indicator showed that 37.9% of the wadeable streams were fully supporting, while 14.3% of the streams were not supporting. A large percentage of the streams had insufficient information to make the assessment because the sites were low gradient and the benthic IBI could not be applied to the data. The stations that were categorized as not supporting were not concentrated in any particular part of the state.

The majority of the wadeable streams were fully supporting for primary and secondary contact recreation. Only 6.1% of the stream miles did not support primary contact recreation, and no violations of the secondary contact recreation standard were observed. In contrast, 82.3% and 95.4% of the stream miles were fully supporting for primary and secondary contact recreation, respectively. The not supporting stations for primary contact recreation were scattered across the state. The insufficient information stations were clustered in two groups, probably reflecting stations that were sampled on the same date.

When applied to the BCG model, the majority of wadable streams were in tiers 2 (17%) and 3 (22%), categories characteristic of streams in good to excellent condition. A minority of wadable streams were in tiers 4 (10%) and 5 (6%), categories indicative of streams in intermediate to poor condition, respectively. All of the tier 4 and 5 stations were located in the southern part of the state. In contrast, all of the stations in the northern part of the state were either tier 2 or 3. Similar to the aquatic life use results obtained for the IBI, a large percentage of the streams had insufficient information for placement into a BCG category because several sites were excluded from the analysis due to the low gradient nature of the sites that were sampled.

The level of correspondence between IBI scores and BCG tiers indicated that percentage of sites attaining full support aquatic life use status based on IBI scores dropped consistently from 90% of sites in tier 2 (10 out of 11 sites) to 0% of sites in tier 5 (0 out of 3 sites). IBI score distributions also declined from tier 2 through tier 5 sites. As indicated in the box and whisker plots, the IBI threshold probably lies within tier 4 of the BCG model, however, the dataset tested here lacks sufficient numbers of sites in these lower tiers to make a definitive conclusion. The results demonstrate there is a moderate level of correspondence between IBI scores and BCG tiers. To our knowledge, this is the first application of an IBI-based aquatic life use determination concurrent with the BCG model for a probabilistic monitoring network. Repetitive applications of the BCG model to a probabilistic monitoring network over time have the added advantage of showing incremental changes in resource condition, while IBI aquatic life use determinations are most helpful in determining the percentages of the resource characterized as fully supporting and non-supporting.

The required data elements for probabilistic assessments in 305(b) reporting are provided as an appendix.

**References**

DES (2006) 2006 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology. NHDES-R-WD-05-29. NH Department of Environmental Services, Watershed Management Bureau, Concord, NH.

USEPA (2005) *Draft document.* Use of Biological Information to Tier Designated Aquatic Life Uses in State and Tribal Water Quality Standards. USEPA Office of Water, Washington, DC. August 10, 2005.

## Appendix A: Section 305(b) Reporting Data Elements

**Table A1: Aquatic Life Use Support**

| Data Element | Result |
|---|---|
| Probabilistic Network Name | New England Wadeable Stream Study |
| Project ID (Assessment Unit ID) | "NHRIV" assessment units of 1st, 2nd, 3rd, and 4th order |
| Target Population | 1st, 2nd, 3rd and 4th order streams in NH |
| Resource Type | River |
| Designated Use | Aquatic Life Use Support |
| Indicator | Benthic macroinvertebrates |
| Size | 9,050 |
| Units | Stream miles |
| Number of sites | 61 stations in NH. Data were collected at 54 stations. Only 34 of the stations were medium or high gradient sites. |
| Percent attaining | 37.9% |
| Percent insufficient information or not assessed | 47.8% |
| Percent not attaining | 14.3% |
| Assessment Data | 20060302 |
| Precision | 95% |
| Confidence | +/-13% |

**Table A2: Primary Contact Recreation**

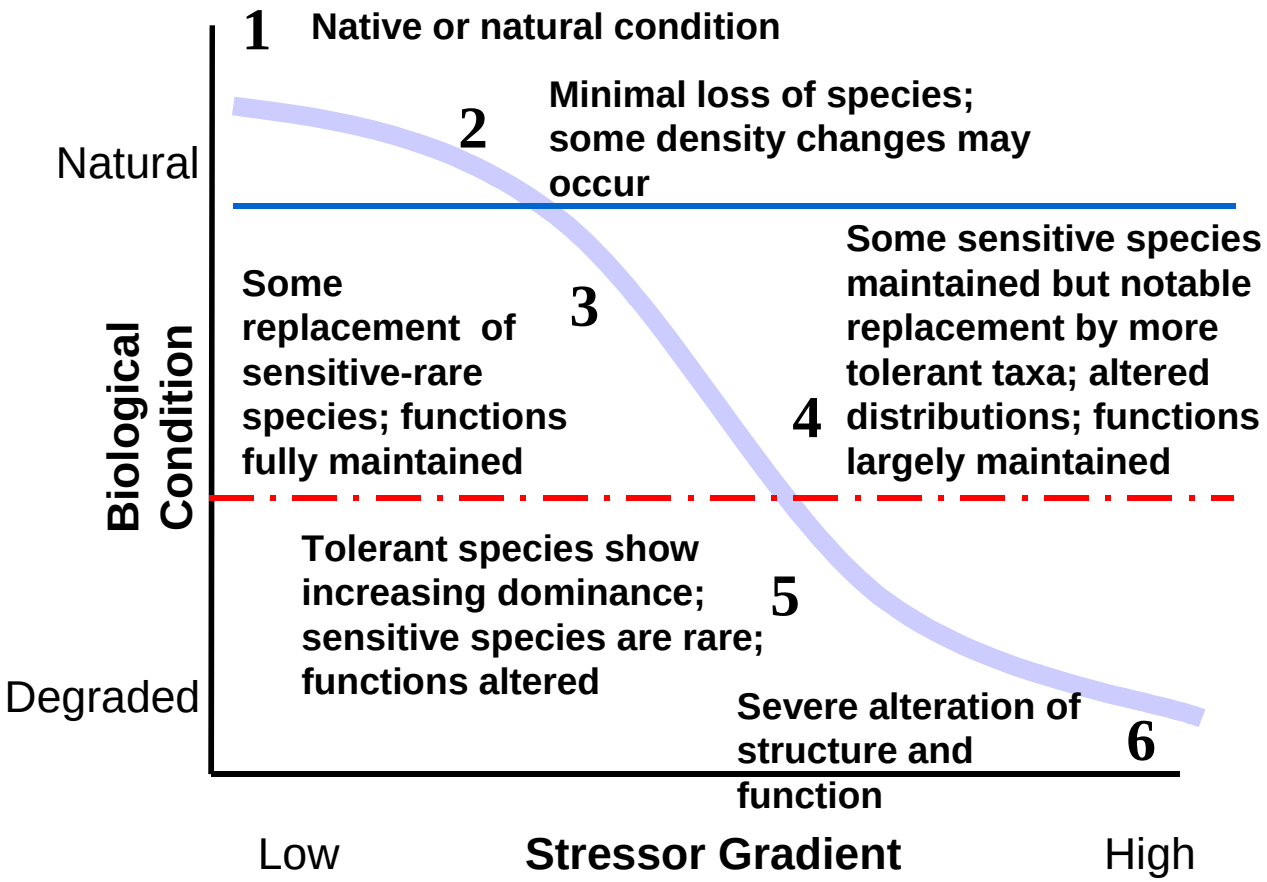
| Data Element | Result |
|---|---|
| Probabilistic Network Name | New England Wadeable Stream Study |
| Project ID (Assessment Unit ID) | "NHRIV" assessment units of 1st, 2nd, 3rd, and 4th order |
| Target Population | 1st, 2nd, 3rd and 4th order streams in NH |
| Resource Type | River |
| Designated Use | Primary Contact Recreation |
| Indicator | *Escherichia coli* |
| Size | 9,050 |
| Units | Stream miles |
| Number of sites | 61 stations in NH. Data were collected at 54 stations. |
| Percent attaining | 83.2% |
| Percent insufficient information or not assessed | 10.7% |
| Percent not attaining | 6.1% |
| Assessment Data | 20060302 |
| Precision | 95% |
| Confidence | +/-10% |

**Table A3: Secondary Contact Recreation**

| Data Element | Result |
|---|---|
| Probabilistic Network Name | New England Wadeable Stream Study |
| Project ID (Assessment Unit ID) | "NHRIV" assessment units of 1st, 2nd, 3rd, and 4th order |
| Target Population | 1st, 2nd, 3rd and 4th order streams in NH |
| Resource Type | River |
| Designated Use | Secondary Contact Recreation |
| Indicator | *Escherichia coli* |
| Size | 9,050 |
| Units | Stream miles |
| Number of sites | 61 stations in NH. Data were collected at 54 stations. |
| Percent attaining | 95.4% |
| Percent insufficient information or not assessed | 4.6% |
| Percent not attaining | 0% |
| Assessment Data | 20060302 |
| Precision | 95% |
| Confidence | +/-6% |

**Appendix B: Biocondition Gradient Model (BCG) Model**

**Schematic of BCG model and corresponding tiers**
**(Borrowed from Susan Davies, MEDEP)**



## Narrative of BCG model tiers (Borrowed from Susan Davies, MEDEP).

**Tier 1: Natural or native condition.**

*Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability.*

**Tier 2: Minimal changes in structure of the biotic community and minimal changes in ecosystem function.**

*Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.*

**Tier 3: Evident changes in structure of the biotic community and minimal changes in ecosystem function.**

*Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive-ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system.*

**Tier 4: Moderate changes in structure of the biotic community with minimal changes in ecosystem function.**

*Moderate changes in structure due to replacement of some sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.*

**Tier 5: Major changes in structure of the biotic community and moderate changes in ecosystem function.**

*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from those expected; organism condition shows signs of physiological stress; ecosystem function shows reduced complexity and redundancy; increased build-up or export of unused materials.*

**Tier 6: Severe changes in structure of the biotic community and major loss of ecosystem function.**

*Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered.*