Water Resources Research Center

Annual Technical Report

FY 1999

Introduction

For Fiscal Year 1999, the New Hampshire Water Resources Research Center (WRRC) was funded by USGS for administration and two new research projects. Administration of the program primarily included grant management, correspondence, and outreach. The two new projects funded addressed water quality and stream hydrology. "Development of Statewide Nutrient Loading Coefficients Through Geographic Information System Aided Analysis" addressed the use of GIS to link water quality in lakes to basin characteristics. "Estimation of Flow-Duration Curves at Ungaged Stream Reaches in New Hampshire and Vermont" developed a technique to estimate flow at ungaged reaches, which will be critically important in establishing in-stream flow requirements for New Hampshire streams. Early in FY 1999, Dr. Thomas Ballestero resigned as Director of the WRRC. In late February of 2000, a new Director was appointed, Dr. William McDowell. This transition also coincided with the loss of dedicated office space for the WRRC and the WRRC library. New Hampshire WRRC is now housed in the College of Life Sciences and Agriculture, and has no dedicated office or laboratory space.

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	A Survey of 50 NH Lakes for Microcystins
Project Number	02
Start Date	09/01/1998
End Date	08/31/2000
Research Category	Water Quality
Focus Category #1	Toxic Substances
Focus Category #2	Water Quality
Focus Category #3	Ecology
Lead Institution	Unversity of New Hampshire

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
James F. Haney	Professor	Unversity of New Hampshire	01
Miyoshi Ikawa	Professor	Unversity of New Hampshire	02

Problem and Research Objectives

Cyanobacteria blooms pose a potential threat to the use of lakes for both recreation and drinking water supplies. There are increasing reports of health problems associated with toxic cyanobacteria such as Microcystis in many parts of the world. Preliminary investigations in New Hampshire lakes indicated the presence of the hepatotoxin microcystin in lakes of varying trophic status. The major objective of this study is to conduct a survey of New Hampshire's lakes to determine which lakes contain toxic cyanobacteria that produce microcystins and evaluate whether there is a direct relationship between the presence of the cyanobacteria toxins and the trophic condition of the lakes.

Methodology

50 study lakes were selected to represent a wide range of lake basin types, nutrient conditions and geographic regions within New Hampshire. During the summer, triplicate samples for toxin analysis were collected from the plankton and from filtered and unfiltered water from each study lake. Parallel samples were also taken for analysis of nutrient (phosphorus and nitrogen) as well as chlorophyll a and dissolved color. Plankton samples were also taken for identification and enumeration. Depth profiles were measured of the light using a underwater probe and data logger as well as temperature, specific conductance, dissolved oxygen, redox, pH, turbidity, and phytoplankton fluorescence using a multiparameter probe. Phytoplankton, zooplankton and lake water were analyzed for microcystins using the enzyme-ligand immunosorbant assay (ELISA) confirmed with high performance liquid chromatography (HPLC).

Principal Findings and Significance

During the summer, 1999, sampling trips were made to approximately 40 of the 50 selected study lakes. The remaining lakes will be sampled during the early summer of 2000. The lakes selected represented a great diversity of trophic conditions, from ultra-oligotrophic to hyper-eutrophic lakes as well as geographic regions including urban/suburban southern New Hampshire, Coastal Plain, White Mountains and the Northern Forest. Laboratory analyses total phosphorus, chlorophyll a and water color have been completed on approximately one half of the lake samples. Remaining chemical analyses, ELISA assays and plankton enumeration will be completed during this fall and winter. Graphic analysis has been completed for most of the analyzed data and statistical analyses will be done as the data sets are completed.

Descriptors

biotoxins, microcystins, Microcystis, cyanobacteria, algae, eutrophication, lakes, water quality

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Development of Statewide Nutrient Loading Coefficients Through Geographic Informa Analysis
Project Number	
Start Date	03/01/1999
End Date	08/31/2000
Research Category	Water Quality
Focus Category #1	Non Point Pollution
Focus Category #2	Nutrients
Focus Category #3	Surface Water
Lead Institution	Unversity of New Hampshire

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Jeffrey A. Schloss	Professional Staff	Unversity of New Hampshire	01

Problem and Research Objectives

The waters of New Hampshire represent a valuable resource contributing to the state's economic base throug and real estate revenues. Some lakes and rivers serve as current or potential water supplies. For most residen boating and fishing registrations) our waters help to insure a high quality of life. New Hampshire currently lea England states in the rate of new development and redevelopment. The long-term consequences of the resulti demands on the state’s precious water resources remain unknown. Of particular concern is the response of ou increasing non-point source pollutant loadings due to watershed development and land use activities. While w budget measurements and modeling have been attempted on a number of watersheds in the state, the recent c Program funding (Section 314) has limited the resources for current and future watershed diagnostic studies.

has ever been made to review the existing data provided from previous studies and to investigate whether sta
loading coefficients can be developed using the powerful statistical and spatial analysis tools now available th

Current water quality models utilized for lake management and diagnostic purposes (when direct water nutrie
been measured) rely heavily on nutrient export coefficients derived primarily from out of state (Reckow et al)
of geographic area, New Hampshire data from Hubbard Brook. This research was initiated to finally make an
integrate the existing data available from local, state, university, and federal watershed studies. Developing ex
from existing studies conducted over different areas of the state will allow for the estimation of watershed loa
confidence. Such coefficients would also allow for the efficient use of limited resources and provide baseline
from which future studies can benefit.

Methodology

1. Review, catalog and conduct a preliminary analysis of past and ongoing watershed studies done by the
Environmental Services, the University of New Hampshire, USGS, US Forest Service, NRCS and regi
by State and Regional Planning Agencies.

    Of 25 known watershed diagnostic studies performed by NH DES, UNH and other agencies data
were compiled. Dates of the studies ranged from June 1981 to the present.

2. Compile the digital data layers and information necessary to perform spatial and general statistical anal
taken here in terms of completeness of data and time of study compared to what is available from the C

    Of the 24 studies catalogued, 168 subwatersheds from 23 of the study watersheds were delineate
digitized. Vector basemaps, raster USGS topography maps and Landsat derived generalized land
created for each of these subwatersheds. Nitrogen data were severely limited so Phosphorus was
Phosphorous loading data were available for only 19 of the studies as 6 studies were either still c
continued field measurements or data work-up. Digitized GIS soils coverage data and digital ele
projections were expected to be completed before the end of this study by NH GRANIT (our sta
depository). However, delays in these independent projects resulted in missing soils coverage for
used in the study. See Table 1 (click Table 1 below to view) for a catalogue of watershed studies
digitized (descriptive, summary and spatial), and those selected for analysis.

    Table 1

3. Compare geographic areas studied, methods, extent, dates of study and select those watershed studies
will yield the best combination of variation and commonality of watershed characteristics.

    Figure 1 displays the locations of the studies. There was generally good representation in terms c
productivity of the study lakes and land cover. The studies were dispersed within four of the six
Phosphorus regions of NH as defined by Rohm, Ommerick and Kiilsgaard (1995) based on lake
and a combination of landscape factors. The two phosphorus regions not represented are limited
spatial extent in New Hampshire, and thus, would include only a small number of lake watershed
surveyed also fall within all three New Hampshire " vegetative ecoregions" as defined by the NH
Study and both level II Ecoregions as defined by EPA BASINS (Lahlou et al 1998) from work b

Figure 1

4. Perform watershed update visits to selected subwatersheds to ground truth existing GIS data, update la selectively re-sample streams to confirm historical data.

   After study reviews, site visits to selected watersheds, review of more recently collected data, co officials, and discussion with agency cooperators, the subwatersheds for combined analysis were screening criteria included:

   1. Subwatershed loading was determined through flow and nutrient monitoring as opposed to landcover or other means.
   2. Completeness of data.
   3. Acceptable accuracy of available generalized landcover data in GIS format.
   4. No major subwatershed changes were known to occur (site visits or disscussions).

   In all, 67 subwatersheds were chosen for use in the analysis covering over 105.6 .thousand acres breakdown of number of subwatersheds selected by lake for this study).

5. Conduct a preliminary analysis (applying "Occum's razor") of the data to determine export coefficient and differences for a series of land-cover types and combinations.

   Subwatersheds were categorized using cladistic analysis (SYSTAT Version 9, 1999, SPSS Inc., of 8 subwatershed types depending on the breakdown of generalized land-cover dominance. Belo the cladistic results:

   - Active Agriculture
   - Highly Urban
   - Mixed Urban/Agriculture/Cleared
   - Highly Deciduous Forest Cover (>73% Deciduous)
   - Deciduous Forest Cover (>58% Deciduous <73%)
   - Mixed Forest Cover with dispersed wetlands
   - Non-deciduous Forest Cover (>55% Non-deciduous)
   - Wetlands

   Table 2 displays the resulting breakdown along with percent cover for the subwatersheds chosen displays the subwatershed export coefficients by the subwatershed "typing" described above. Tab statistics on these data. Figure 3 displays the non-parametric box and whisker analysis of these re Figure 4 contain similar descriptions and analyses on the subwatershed export coefficients after t normalized for yearly precipitation.

   Table 2

   Table 2 continued

Figure 2

Table 3

Figure 3

As can be seen, within each of these groupings there is a relatively wide range export coefficients further examination using the available GIS coverages the average watershed slope was an impor of the subwatersheds reresenting the higher loadings in their grouping. Also, subwatersheds cons drainages that were derived from highway, roads, camp roads and low intensity development we the higher end of loadings in the forested groupings. Thus a useful but unavailable GIS coverage indication of development intensity within primarily forested areas. Available census block group landcover interpretation (Multi-resolution Land Characteristics produced by Pacific Meridian Re contract to USGS) did not account very well for development density. As a result there is the wi phosphorus export among forested subwatersheds. This may be better addressed using the expec and local road data or if the statewide 911-Emergency coverage is made available. Otherwise on windshield surveys or other means of data collection is necessary to characterize development in landscape since the GIS coverage is currently lacking for our predominately rural, low density de

On the lower range of export for each of the land cover groupings subwatersheds generally repre more extensive riparian buffer or wetland complexes or relatively flat vegetated areas and undev forested areas.

Table 4

Figure 4

6. Compile nutrient export coefficients that were previously recommended and/or used in earlier and ongo allow for the determination of under or over estimations based on the results of this study.

Review of the NH watershed studies as well as relevant and commonly cited publications was co
coefficients were compared with the outcomes of this study. The survey of historical efforts indic
used for similar land-cover / land-use categories varied between studies independent of ecoregion
investigator. One study provided both chosen coefficients and the expected range for those coeff
range data allows for the generation of probability functions around the model estimates so they
important in model interpretation. Generally, only a limited range of land-cover or land-use class
projects that involved measured loadings while a wider range of classes were employed for empi
that involved no or limited field sampling. Table 5 displays a listing of export coefficient estimati
studies reviewed.

Table 5

Principal Findings and Significance

Principal Findings

1. The range of export coefficients for various landcover combinations (types) found throughout New Ha summarized for the first time.

2. Initial analyses of the data compiled disclosed that the differences between export coefficients could be incorporating other descriptive landscape level data available. This ranged through a series of spatial sc
   1. Landcover classification and "typing".
   2. Generalized subwatershed slope.
   3. Location of potentially impacting land uses to channelized flow, tributaries or shorelines.

3. Disturbed land, shoreline development and riparian buffer and wetland complex extent were other facto on the loadings.

4. The level of development intensity under forest cover oftentimes was a major factor that determined w loadings a subwatershed fell. GIS data available for analysis did not allow for accurate estimation of de

5. Standardizing the export coefficients to a "normal" precipitation year decreased the variation within th and brought coefficients for similar land classes by different investigators using different techniques slig However, investigation into each separate study disclosed the importance of major storm events in the loadings measured for each month when comparing multiyear studies. Thus, the utility of normalizing t for general management purposes or setting target levels while non-normalized data would be best for response modeling for a given year and in management practice evaluations.

6. Prediction improvements should occur through the use of these newly summarized coefficients and ran coefficients used currently and in previous studies which might have overestimated forested landcover underestimated the range of urban and agricultural land cover export in light of these results.

Statement of Benefits

The results of this investigation will allow for the improvement of predictive models used for watershed plann
The benefits of this are wide ranging from assisting watershed stewardship education efforts throughout the s

providing existing watershed based programs like the EPA Basins Model Initiative, the statewide Unified Wa
Initiative (under the federal Clean Water Action Program) as well as the regional initiative (US EPA Region 1
develop total daily maximum loading criteria (TMDLs). The information collected digitized and summarized
modeling efforts of New Hampshire's pristine lakes and rivers (and similar systems throughout our region). It
illustrate the importance (and justification) of proposed and existing regulations, and best management practi
makers and the public.

Relevance to Related Research

No statewide or region-wide analysis has previously been made to develop nutrient export coefficients. Rohm
Kiilsgard (1995), using existing nutrient data divided NH into six phosphorus "regions" based on historical in
data, physiography, land-cover/land-use, vegetation, soil type and bedrock and surficial geology. However, th
lake phosphorus data and did not analyze actual watershed loadings at the watershed or lake tributary level. T
more recent data from stream loading measurements and investigated relationships for characteristic watershe
coefficients.

While much pioneering work on forest export coefficients and logging impacts on watershed water quality ha
Hampshire (Pierce et al 1970), these studies are limited to totally forested watersheds and logging impacts. T
these land cover/land use categories but also allow for the comparison to a wide range of watershed cover an
urban, agriculture, wetlands, low intensity and high intensity development.

Reckow did develop a New England region-wide modification of his spreadsheet based lake response model
NELAKES (described in Draft Report to EPA 1990: Regional Lake Eutrophication Models). He has been ve
seeing the development of GIS derived coefficients for model improvement (Dr. Ken Reckow, Duke Univers
personal communications). He has also communicated that work along these lines would further and improve
estimation of such coefficients as described in "Modeling Phosphorous Loading and Lake Response Under U
et al 1980) and improve the error estimations of existing models that are in use throughout the region.

In EPA's National Strategy for the Development of Regional Nutrient Criteria (EPA-822-F-98-002, Office o
announced that a technical guidance manual for assessing trophic state and developing region-specific nutrien
under development. A draft of this document has been made available for review. Results from this project sh
review process in these efforts. In addition, the results of this study should be quite useful in the development
models as well as models currently used by cooperating agencies like QUAL2E (Brown and Barnswell 1987)
which are currently being used in the EPA BASINS GIS Watershed Analysis System (Lahlou et al 1998).

Information Transfer

This project has already had impacts in terms of information transfer. The information is being shared betwee
researchers and managers that deal with water quality monitoring. Particularly the Lakes Assessment Program
Water Protection Program at NH DES have been involved and will incorporate the new findings in their curr
Initially, we will re-visit the current NE Lakes model used by both of our programs and adjust the coefficients
accordingly (also see Reckow discussion in Relevance to Related Research above). There has also been intere
England Regional Assessment Program under the US Global Change Research Program to incorporate our fi
global change projections and their modeling efforts. This is being done in conjunction with the NH DES Loc
Assessment Project.

The watershed and subwatershed delineations created through this project as well as any of the processed GI available to faculty, students, and cooperating agencies as these delineations go further than the current Hydr delineations in terms of resolution (scale). They will be incorporated into a shared web site between UNH and allow Internet access to lake watershed data. Much of the data compiled is also being used for an ongoing an watersheds throughout New Hampshire for an EPA STAR program funded project looking into watershed cl may influence the generation of cyanotoxins from blue green algae.

Future Research Potential

Initially, the scope of this project was to include additional landscape level analysis of impervious cover vs rip attempt to explain export coefficient variations. However, the expected improved impervious surface coverag produced by the Complex Systems Research Center under an unrelated grant was delayed. It is expected to b the year though and would open up further analysis possibilities for the data generated from this project. Part this investigator would be the improved impervious cover coverage. Further work using this project's data m determination of the critical levels of impervious cover that most impact nutrient loadings. Imperviousness ha "hot" topic in watershed management, planning and concern over "sprawl" (see discussions in Shueler (1994) Gibbons (1996)).

This study concluded that only limited agricultural lands export data was available in the previous watershed funding through the Non-point Source Program of NH DES to Cooperative Extension investigators will addr and investigate the efficiencies a range of buffer BMPs.

In addition, a new spatial model for Arcview GIS developed by the EPA, ATILA, has been made available to will be incorporating data generated from this effort into the new ATILA GIS model to test its usefulness at p phosphorous export coefficients. Finally, the SPARROW Model used on Chesapeake Bay (Smith et al 1997) by EPA New England Lake Nutrient Assessment Team for applications to lake watersheds (meetings facilitat Interstate Water Pollution Control Commission 1/20/99 Lowell MA). This study's data may be of use in atter the use of SPARROW in smaller sized watersheds.

Students Supported Directly from Project

While only a few students were actually supported through the project's federal funding, many students partic aspect of the project through the use of other federal and local funds supporting the efforts of the NH Lakes L Program. In general, each student worked between 10 and 20 hours a week during the fall and spring semeste hours a week during the summer session. Students worked in all aspects of the project which included field m and flow, laboratory analysis, data input, data reduction and data analysis. In all, 4 undergraduate students an were directly supported by the project while 12 additional undergraduate students worked on various aspects

References Cited

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Descriptors

Eutrophication, Geographic Information Systems, Land Use, Land-Water Interactions, Nutrient Loading Coe
Phosphorous, Spatial Analysis, Water Quality Modeling, Watershed Management.

Articles in Refereed Scientific Journals

We expect to continue some additional analyses and submit the results of this project to an appropriate journa

Book Chapters

Dissertations

None Completed – but Robert Craycraft a MS student in Natural Resources (Water Resources) utilized this p
additional time in the field to direct his thesis proposal. Additionally, this project may serve as the preliminary
Principal Investigator in further studies that will be used for his dissertation.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

We will produce an internal publication: Squam Lakes Watershed Project Report: Nutrient / Water Budgets a
with the Squam Lakes Association in the spring of 2001 that will use data generated from this project. In add
the interpretation of some of our finding will be included in the final report of the final report of the New Eng
Assessment Project, part of the US Global Change Research Program.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Estimation of Flow-Duration Curves at Ungaged Stream Reaches in New Hampshire and Vermont
Project Number	
Start Date	06/01/1999
End Date	08/31/2000
Research Category	Climate and Hydrologic Processes
Focus Category #1	Water Quantity
Focus Category #2	Surface Water
Focus Category #3	Hydrology
Lead Institution	Unversity of New Hampshire

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
S. Lawrence Dingman	Professor	Unversity of New Hampshire	01

Problem and Research Objectives

Magnitude and frequency of streamflow are two of the components of flow regime that together determine the integrity of aquatic ecosystems through their on impact water quality, energy sources for stream biota, the physical parameters of aquatic habitat, and biotic interactions. As all withdrawal uses of water affect the magnitude and frequency of downstream flows, the problem of instream flows has emerged as one of the region's major water-resource management issues. It has been a central issue in most hydropower dam licensing and relicensing proceedings for the last two decades. New developments such as snow-making threaten to alter stream regimes in pristine upland watersheds. The State of New Hampshire has recognized the severity and widespread nature of these impacts and has been developing an instream-flow program to develop guidelines and rules for protecting instream flows threatened by withdrawal uses and flow regulation.

Flow-duration curves (FDCs) are cumulative-frequency plots of mean daily discharge, hence they depict the magnitude and frequency of streamflow at a stream reach. They can be readily constructed for stream reaches which have been gaged continuously for a suitable period. However, magnitude-frequency information is usually required for reaches that have not been gaged.

The objective of the research proposed here is to develop improved techniques for estimating natural

FDCs (FDCs unaffected by withdrawal or regulation) at ungaged stream reaches in New Hampshire and Vermont. Such curves would provide a baseline against which to evaluate the effects of proposed water-use, flow-regulation, or land-use developments on streamflow magnitude and frequency.

Methodology

The overall research plan involves the following steps:

1. Identify a probability distribution that appears to describe FDCs for unregulated stream reaches in NH and VT.

2. Establish quantitative relations between the parameters of the distribution and characteristics of drainage basins that can be determined a priori from maps, GIS data bases, or other sources.

3. Use the relationships established in Step 2 to estimate FDCs at ungaged reaches.

4. Determine the utility of this approach to estimating FDCs for ungaged unregulated stream reaches in NH and VT.

Principal Findings and Significance

Records from 44 gaging stations in NH and VT fit our criteria of having no significant regulation and at least 10 yr of daily streamflow records. To facilitate comparison among drainage basins of varying size, we divided the actual measured flows at these stations by drainage area to give the specific discharge, q. We then constructed median-annual FDCs for the specific discharges at each station.

Using L-moment analysis, we determined that the Generalized Pareto Distribution (GPD) appeared to provide a good fit to the FDCs of the 44 stations. This distribution can be written as

$EP(q) = [1 - k \cdot (q - x)/a]1/k$ (1)

where q is a particular value of specific discharge, EP(q) is the probability that specific discharge equals or exceeds q, and k, a, and x are parameters of the distribution. Basin-characteristic data were readily available for 31 of the 44 stations that fit our criteria. Of these, 9 were randomly selected and assigned to a validation data set, leaving 22 stations in the calibration data set. Using automated multiple-regression analysis, the best-fit relations between distribution parameters and basin characteristics were found to be:

$k = - 0.635 – 0.000046 \cdot Z + 0.009 \cdot PDF$ (2)

$a = - 0.604 + 0.000151 \cdot Z + 0.404 \cdot PDF$ (3)

$x = 0.00022 \cdot Z – 0.0058 \cdot F + 0.0114 \cdot PDF – 0.003 \cdot L$, (4)

where Z is mean basin elevation (ft), PDF is mean basin precipitation-delivery factor (in./yr), Zmax is maximum basin elevation (ft), S is main channel slope (ft/mi), F is percent of basin with forest cover, L is main channel length (mi).

Equations (2) – (4) were then used to estimate k, a, and x for the 9 stations in the validation data set, the resulting values substituted into Equation (1), and the resulting estimated GPD-FDCs compared with the actual FDCs.

Comparisons of predicted with observed values of flow values associated with specified exceedence probabilities were disappointing. Table 1 gives the average deviations, the range of deviations, and the percentage of stations with deviations less than 15% for various values of exceedence probability.

Table 1.

ExceedenceProbability (%)	Average Deviation(%)	Range of Deviations(%)	Number of Stations with < 15% Deviation
98	104	-45 to 415	0/9
95	95	-30 to 215	0/9
90	74	-5 to 157	1/9
75	44	-4 to 95	3/9
50	32	-4 to 67	3/9
25	20	-3 to 41	4/9
10	13	-1 to 25	5/9
5	12	-3 to 26	5/9

Descriptors

Flow duration; Instream flow; Water quality management; Water allocation; Streamflow depletion; Aquatic habitats; New Hampshire; Vermont

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	12	N/A	N/A	N/A	12
Masters	5	N/A	N/A	N/A	5
Ph.D.	N/A	N/A	N/A	N/A	N/A
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	17	N/A	N/A	N/A	17

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications