Distribution, Status and Threats to Brook trout within the eastern United States

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Abstract. ---- We summarized existing knowledge regarding the distribution and status of naturally reproducing populations of brook trout *Salvelinus fontinalis* across their native range in the eastern United States (east of Ohio) a region that represents approximately 25% of the species native range and 70% of the native range in the United States. Our results show that brook trout remain in 3,344 subwatersheds and are extirpated from 1,166 subwatersheds of their potential (historic) range within the study area. We determined that 5,837 subwatersheds within the potential historic range never had the habitat to have self-reproducing brook trout populations. Brook trout status could not be determined on another 793 subwatersheds because of the lack of data. Brook trout were known to be absent in another 260 subwatersheds but it was not known if they were extirpated or never occurred in these subwatersheds. In subwatersheds where reproducing populations of brook trout were present 45% have lost over 50% of the habitat supporting reproducing brook trout (Category: Present: Greatly Reduced); 15 % have lost between 10% and 49% of habitat supporting reproducing brook trout (Category: Present: Reduced); 9 % have lost less than 10% of the habitat supporting reproducing brook trout (Category: Present: Intact); and 31 % did not have data to determine the % of reproducing habitat lost (Category: Present: Qualitative data). At the subwatershed level high water temperature, agriculture, urbanization, one or more exotic fish species and poor riparian habitat were identified by expert local fisheries biologists as the top reasons for the loss of reproducing brook trout somewhere in the subwatershed. The percentage of human land use in each subwatershed in the Mid -Atlantic Highland region (Virginia, West Virginia, Maryland, Pennsylvania, New Jersey) was a useful predictor of brook trout distribution and status. Reproducing populations of brook trout are more likely to be extirpated from subwatersheds where the percentage of land with human uses was greater than 18%. Intact populations (>50%) are more likely in subwatersheds where the percentage of human uses is less than 10%. Continued habitat loss associated with land use practices, existing and new populations of naturalized exotic coldwater and warm water fishes threaten remaining brook trout populations. Even with no further habitat loss or increase in exotic fishes, existing fragmentation could lead to continuing extirpations at the subwatershed scale.

The assessment of the status of brook trout *Salvelinus fontinalis* populations across the eastern United States is a timely task because numerous state and federal agencies, non-government organizations and anglers have expressed concern that populations of brook trout in their native range in the eastern United States are declining or being locally extirpated. Many physical, chemical and biological watershed level changes over the last two-hundred years have occurred in the native range of brook trout in the eastern United States (MacCrimmon and Campbell 1969; Jenkins and Burkehead 1993; Marschall and Crowder 1996; Yarnell 1998).

Historic and current land use practices (King 1937; King 1939; Lennon 1967; Kelly et al. 1980; Nislow and Lowe 2003), changes in water quality (acid mine drainage, acid rain (Fiss and Carline 1993; Gagen and Carline 1993; Clayton et al. 1998; Hudy et al. 2000; Driscoll et al. 2001), increased water temperature (Meisner 1990), euthrophication) the spread of exotic and non-native coldwater (Moore et al. 1983; Larson and Moore 1985; Moore and Ridley 1986; Strange and Habera 1998) and warmwater fishes, fragmentation of habitats by dams and roads (Belford and Gould 1989; Gibson et al. 2005), habitat destruction, stream channelization, poor riparian management, sediment (Curry et al. 2003) and natural stochastic events (Roghair et al. 2002) have eliminated or severely reduced brook trout populations at a local or regional scale (Bivens et al. 1985; SAMAB 1996a; SAMAB 1996b; Galbreath et al. 2001; Habera et al. 2001; McDougal et al. 2001). However the cumulative impacts of these historic and current threats have not been evaluated at a large scale. Evaluations of the integrity of native brook trout watersheds over their native range are needed to guide decision makers, managers and publics in setting priorities for watershed level restoration, inventory and monitoring programs. Large-scale assessments for many aquatic species have been useful in identifying and quantifying: problems, information gaps, restoration priorities and funding needs (Williams et al. 1993; Davis and Simon 1995; Frissell and Bayles 1996; Warren et al. 1997; Master et al. 1998). Previous projects at the landscape scale on bull trout (Rieman et al. 1997) and Pacific salmon (Thurow et al. 1997) have been useful in developing large-scale conservation and restoration efforts and have increased public awareness and funding to these resources. Our goal is to determine the distribution, status and threats to brook trout across a major part of the species range in the eastern United States. Our approach was based on a summary of current knowledge of reproducing brook trout populations provided by more than 17 agencies managing brook trout throughout the study area.

Specific objectives were to 1) consistently classify subwatersheds throughout the study area based on the percentage of habitats still maintaining reproducing populations of brook trout, 2) utilize expert opinion to determine threats to reproducing populations of brook trout in each subwatershed, 3) develop a pilot study in the Mid-Atlantic Highlands region to evaluate relationships among brook trout classification categories and anthropogenic impact metrics of the entire subwatershed and watershed corridor 4) make an interactive database available on the internet that utilizes the classification categories and threats information.

Background and Study Area

We used 6th level Hydrologic Unit (HU) watersheds (mean size 8,927 ha, SD 7,589) (referred throughout the remainder of the paper as subwatersheds) for this assessment (Seaber et al. 1987; McDougal et al. 2001; EPA 2002; USGS 2002b). Subwatersheds were chosen because: 1) they are the smallest size watershed where data was currently available, 2) it is a level of great interest for land management (McDougal et al. 2001), and 3) it is a size where plans can be developed for conservation management at a reasonable scale (Moyle and Yoshiyama 1994; Master et al. 1998). Larger watersheds (4th and 5th level HU's) were determined by managers to be of little value in managing and restoring brook trout and stream segments were determined to be of too fine a scale because of the number of segments (n > 375,000 in the study area) and the high percentage of stream segments with little or no data. In cases where subwatersheds have not been finalized we used the latest available drafts available from the USDA Natural Resources Conservation Service. Subwatershed level delineations were not available for the state of New York at the time of this report and 5th level watersheds were used. These averaged approximately twice the average size of the subwatersheds throughout the rest of the study area. We made note during the classification of which subwatersheds could potentially change classification categories once smaller watershed delineations became available. The 6th level watersheds for the state of New Jersey were smaller than the other states in the assessment. We plan on consolidating the New Jersey watersheds into sizes approximating the average subwatershed size for the other states by the time of final draft of this report. In our study we classified all subwatersheds (n = 11,374) within the native distribution of brook trout in the eastern United States (MacCrimmon and Campell 1969; Behnke 2002) (Figure 1).

Methods

Classification Key

The types of data available from the 17 states limited the types of questions we could answer. The myriad of databases with different objectives, methods, completeness, quality and resolution made consistent answers to many questions unanswerable at the scale of the study area. A least common denominator approach was necessary even though it eliminated finer scale data that was not available for every subwatershed.

We choose to focus on a classification system designed to consistently classify subwatersheds throughout the study area based on the percentage of habitat in each subwatershed still maintaining reproducing populations of brook trout. The classification categories do not assess all wild trout resources, recreational fishing quality or potential, past or current management practices or viability. Naturally reproducing populations regardless of life history strategy or genetic differences were treated equally. Genetic information is important (Krueger and Menzel 1979; Stoneking et al. 1981; Perkins et al. 1993; Kriegler et al. 1995; Guffey 1998; Hayes et al. 1996; Hall et al. 2002; Epifanio et al. 2003) but was beyond the scope of this study. No attempt was made to distinguish among different life history strategies or possible genetic differences because this data was not available or unknown for over 80% of the subwatersheds. In addition because of past stocking practices and the existence of many different populations in one subwatershed the subwatershed level may not be the most appropriate scale to evaluate many genetic questions.

We developed a dichotomous key to classify brook trout distribution by subwatershed (Appendix 1 Table A1, Table 1). Each couplet in the key was designed to be mutually exclusive with consistent definitions and rules. The benchmark was self-sustaining reproducing brook trout populations under historic (pre-European settlement) conditions. We developed several rules to consistently determine the percentages of lost reproducing brook trout habitat in each subwatershed. The presence of reproducing cold water exotics or non-native coldwater fish species within the native range of brook trout (MacCrimmon and Campbell 1969) was considered as proof that brook trout should have occurred in that habitat (Exceptions being coldwater tailwater habitats in previously warm water streams). Warm water habitats and transient habitats (does not support spawning or extended rearing habitat but functions only as migration corridors, staging habitat, wintering area for moving fish) within the watershed were not counted in determining the percentage of habitat supporting reproducing brook trout. The following rules were used to consistently determine loss of reproducing brook trout habitat:

1) Documented loss of reproducing brook trout populations by current or historical reference data.
2) Exotic or non-native coldwater species are greater than 90% of the coldwater fish biomass or density.
3) Brook trout carrying capacity reduced by greater than 90% from historic or reference data within the watershed.
4) Documented water chemistry (documented acid mine drainage, acid rain, etc.) or water temperature changes (changes from habitat alterations i.e. dams, riparian habitat loss, channelization) that no longer support reproducing brook trout.

5) Inundation of brook trout habitat by reservoirs (conversion from coldwater lotic habitat to warm water lentic habitat)

For consistency purposes the authors made all subwatershed classification calls. The classifications were first made based strictly on data provided to the authors and than again based on validation with local experts during the site visits. At the site validation level two authors independently classified the subwatersheds after listening to the local expert and asking additional questions. If there was disagreement in the classification all information was again run through the classification key to see if agreement could be reached. If agreement could not be reached on the subwatershed or enough data was not available to distinguish among classification categories the watershed was classified as 1.0 Unknown or 4.0 Present. The on site validation process resulted in changes from the original (data only) classification category. These category changes occurred from 2% to 30 % of the time, and usually resulted from additional data being available (new data currently not in corporate database) or improper interpretation of the original data provided. At the validation level, the two authors independently agreed on the classification category 96 % of the time. Local experts unfamiliar with the classification key and consistency rules agreed approximately 87% of the time on the first call and 98% of the time after running the available information through the key the second time. Most disagreements in classifications occurred early in the site visits and dropped dramatically after the local experts became familiar with the key and objectives of the assessment. Separate population status calls were made for lotic and lentic habitats when both occurred within the subwatershed.

Threats

During the validation site visit professional fisheries biologists familiar with the area were asked to list all threats to both lotic and lentic brook trout populations in each subwatershed (except categories 1.0 Unknown, 1.1 Absent: Unknown history or 2.0 Never Occurred (Appendix 1 Table A2). Threats were characterized as Level 1: high threat (life cycle component eliminated); Level 2: medium threat (life cycle component reduced but not eliminated); Level 3: low threat (general threat no documented loss or reduction of life cycle). Historic threats that are currently not relevant for restoration were designated separately. For example historic forestry eliminated brook trout from a stream but the area is currently a sub-division.

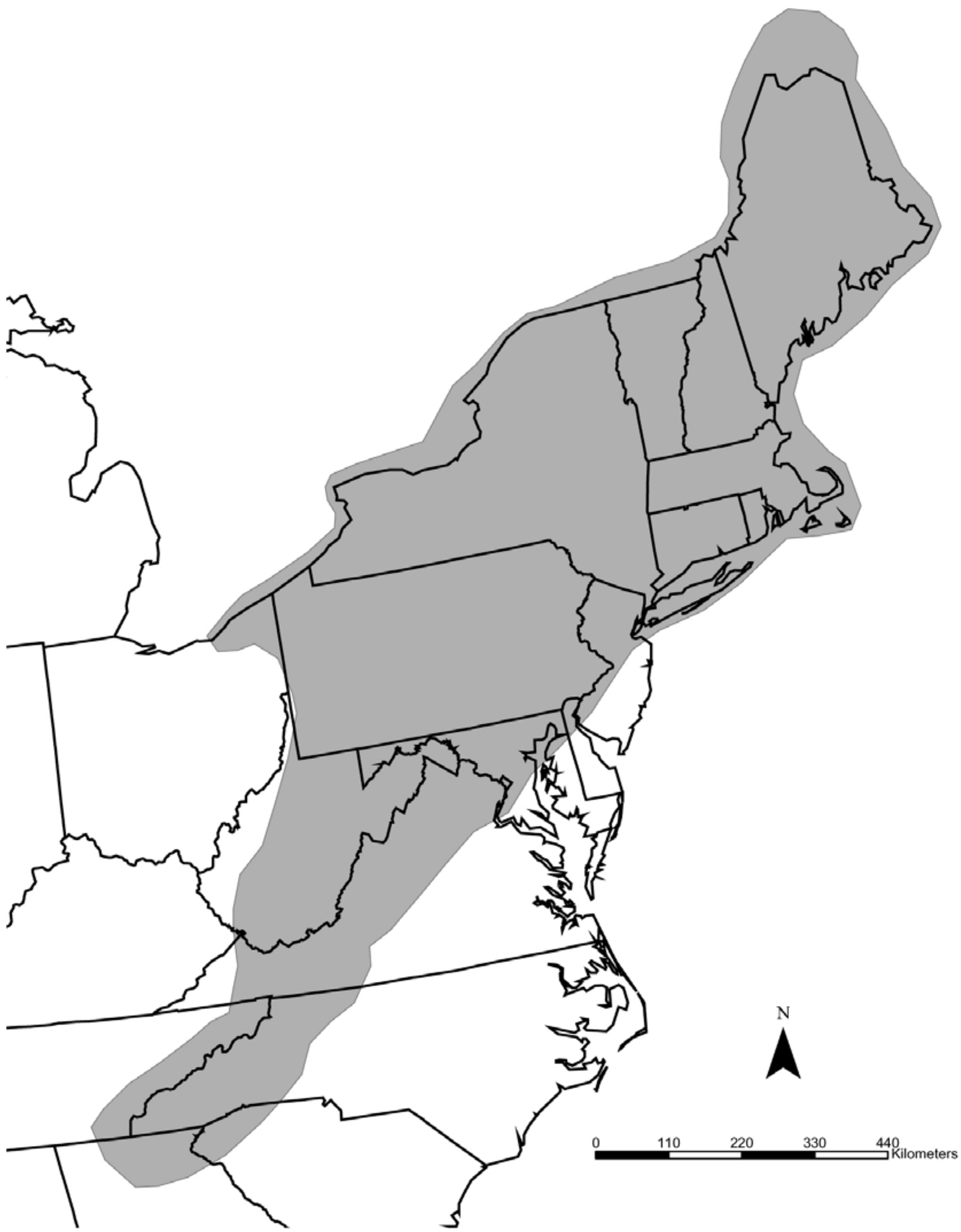

Figure 1. Study Area

Table 1. Summary of watershed level brook trout population classifications and characteristics. See Appendix 1 table A2 for specific characteristics, category 6.0 dropped in final analysis.

Classification categories for lotic and lentic habitats	Summary Characteristics
Classification 1.0 Unknown	No data or not enough data to classify further.
Classification 1.1 Absent: unknown history	Brook trout currently not in watershed; unknown if extirpated or never occurred.
Classification 2.0 Never occurred	Historic reproducing populations never occurred.
Classification 3.0 Extirpated	All historic reproducing populations extirpated.
Classification 4.0 Present:Unknown	No quantitative data; qualitative data show presence.
Classification 5.0 Present: Intact large	High percentage (>90%) of historic habitat occupied by reproducing populations, populations greater than 5,000 individuals or 500 adults.
Classification 6.0 Present: Intact small	High percentage (>90%) historic habitat occupied by reproducing populations, populations less than 5,000 individuals or 500 adults.
Classification 7.0 Present: Reduced	Reduced percentage (50% and 90%) of historic habitat occupied by naturally reproducing brook trout.
Classification 8.0 Present: Greatly reduced	Greatly reduced percentage (1% and 49%) of historic habitat occupied by naturally reproducing brook trout.

Pilot Study Mid-Atlantic Highlands

Because the identification of threats was based on professional opinion and was not repeatable we conducted a pilot study in the Mid-Atlantic Highlands region based on quantitative, repeatable land use metrics that acted as surrogates for the threats identified by expert opinion. We assessed whole watershed and water corridor metrics instead of site-specific variables (Moyle and Randle 1998). Watershed level metric(s) can assist mangers in their evaluations of watershed health by giving an indicator of overall health when many anthropogenic factors may be contributing to a problem and by assisting in identifying key limiting factors (Barbour et al. 1999; McCormick et al. 2001). We tested many models using both single and multiple watershed and watershed corridor metrics to 1) correctly predict brook trout classification categories (for subwatersheds classified as unknown and Present: Qualitative data only) and to 2) provide potential thresholds for various land uses to assist natural resource managers in the protection and restoration of brook trout. A complete assessment of these land use metrics for all watersheds and all metrics will be available in January 2005

Numerous subwatershed and subwatershed water corridor metrics were developed for the states in the Mid-Atlantic Highlands (Table 2). We screened candidate metrics for 1) completeness, 2) redundancy, 3) range, 4) variability and 5) responsiveness (Hughes et al. 1998; McCormick et al. 2001). Candidate metrics were required to have the same data resolution and definitions for all subwatersheds and were obtained and/or developed as a Geographic Information System (GIS) to allow for data analysis in a spatial context (Lo and Yueng 2002). Many potential databases (metrics) were eliminated from consideration because they were not available for all watersheds at the same or a suitable resolution.

The water corridor was defined as 100 m on both sides of all streams and lakes within the subwatershed. The National Hydrography Dataset (NHD) (1:100,000) layers were used for streams and lakes (USGS 1994). Data on roads was developed using improved Topological Integrated Geographic Encoding and Referencing system (TIGER) data (Navtech 2001). Fragmentation at the watershed level was indicated by the number of dams per km^2 of watershed and was calculated from the National Inventory of Dams (NID) (United States Army Corps of Engineers 1998). Fragmentation at the water corridor level was indicated by the number of road crossings per kilometer of stream (Whalen 2004). Land use at the subwatershed level was indicated by the percentage of the subwatershed classified as human use in the National Land Cover Data (NLCD)(USGS 2002a). The NLCD was produced using satellite imagery data acquired in 30 m grid coverage. Human use includes: low and high intensity residential, transitional, orchards/vines, pasture/hay, row crops, small grain crops, urban, recreation, quarries/mines/gravel and commercial/industrial/transportation classifications. Elevation data was from the 30m National Elevation Dataset (NED)(USGS 2004). Land use at the water corridor level was indicated by the percentage of human land uses within the water corridor. The water corridor level metric for human population was the percentage of the corridor that was designated as high or low residential use in the NLCD.

The relationship between brook trout classification status and human intervention as measured by anthropogenic subwatershed level metrics was modeled using logistic regression (Collett 2003). Other researchers have suggested and used methods such as regression trees (Thurow et al. 1997), discriminate analysis and neural networks to predict classification status. While these methods are also useful we favored logistic regression because it produces an estimate of the probability of the different brook trout classifications and also produces inference on the importance of factors influencing brook trout classification status. For example with logistic regression the level of human use associated with a potential effect level may be estimated along with the uncertainty in the estimate. As part of a sensitivity analysis prediction ability of the other methods were evaluated.

We focused on two approaches for prediction with logistic regression. First, we summarized status using a binary status variable (presence/absence). To do this all the categories associated with presence were combined (Present: Qualitative data; Present: Intact; Present: Reduced, Present: Greatly Reduced) and compared to Extirpated. In the second analysis, we created a trinomial status variable with extirpation, Present: Greatly reduced, and various levels of presence (Present: Intact and Present: Reduced). These variables were then treated as dependent variables in the logistic regression with human use variables as the predictor variables.

Logistic regression analysis, in the case of a binary variable, models *p*, the probability that brook trout is one of the classification categories in terms of one or more predictor variables. The model is nonlinear and has an “S” shape, increasing as a function of the variables. If there are k predictor variables used to model a classification category, the model may be written in terms of the probability of presence as

$$\Pr(\text{species present}) = p = \frac{\exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k)}$$

where the *x*'s corresponds to the *k* measured variables used in the model and $\beta_0, \beta_1, ..., \beta_k$ are the associated parameters. The model can be transformed to a linear model using the logit transformation:

$$\text{logit}(p) = \log(\frac{p}{1-p}) = \beta_0 + \beta_1 x_1 + ... + \beta_k x_k$$

Although the model is linear, the fitting process is the not the same as linear regression because the dependent variable is binary or trinomial. The model is fitted using Proc Logistic in SAS using iterative methods of maximum likelihood. Transformations for individual predictors were evaluated using a box-cox transformation. The optimal transformation was rounded prior to application. The lack of fit of the model was evaluated using the Hosmer-Lemenshow test. Residuals and influence were checked using standard methods.

In the case of three categories, we used methods of ordinal logistic regression that results in two S shaped curves that differ in intercept but have similar shape. From these curves probabilities for each category may be computed. For this model we have three probabilities $p_1, p_2,$ and p_3. Because these must sum to 1 we only need to model two of the probabilities. A simple model to do this is to assume the same relationship with the predictors but have a different intercept i.e.,

$$\text{logit}(p_i) = \beta_{0i} + \beta_1 x_1 + ... + \beta_k x_k$$

Other models, allowing for different intercepts and slopes were also evaluated.

To find a set of important predictors, we fit a variety of models with a focus on prediction of the probability of brook trout being present in the subwatershed. Variable selection techniques were used to reduce the number of variables considered to a smaller set. Models were evaluated for individual states as well as for the combined set of states. We summarized the models using prediction ability based on the holdout method. Logistic regression and discriminant analysis was run using SAS, Version 9 and CART (Steinberg and Colla, 1997) was used to fit regression trees.

Table 2. Descriptions of subwatershed level metrics

General threat	Metric	Description
Sedimentation	RDKM_SQKM	Road kilometers per square kilometers of land
	RDKM_SQKM_C	Road kilometers per square kilometers of land in corridor
Fragmentation	DAMS_SQKM	Number of dams per square kilometer
	RDKM_SQKM_CORRIDOR	Road/Stream crossings per stream kilometer in the water corridor
	XNGS_ST_KM	Road/stream crossings per stream kilometer in subwatershed
	DAMSPERHUC	Number of dams per watershed
Human Population	Human_population **	Human population 2005 in subwatershed
	PRCNT_RESDNTCOR	Percent High and low Residential use in the water corridor
Air/water quality	NO3_SO4**	Nitrate and sulfate deposition kg/ha in subwatershed
	PRCNTGREAT**	= Percentage of soils in the water corridor with a pH equal to or greater than 5.0
	PRCNTLESS**	= Percentage of soils in the water corridor with a pH less than 5.0
Land Use	PRCNT_HUMAN	Total Percent Human Uses in subwatershed
	Low_res	Low residential use
	High_res	High residential use
	Qry_mine_gpit	Quarry/mine/gravel pit
	Indust_trans	Commercial/industrial/transportation
	Trans	Transitional
	Pasture_hay	Pasture/Hay
	Row_crops	Row crops
	Urban_rec	Urban recreation
	PRCNT_HUMANCOR	Total Percent Human Uses in the water corridor
	Low_resC	Low residential use
	High_resC	High residential use
	Qry_mine_gpitC	Quarry/mine/gravel pit
	Indust_transC	Commercial/industrial/transportation
	TransC	Transitional
	Pasture_hayC	Pasture/Hay
	Row_cropsC	Row crops
	Urban_recC	Urban recreation
	% Natural	Total Percent natural land uses in the subwatershed
	Deciduous	Total percentage deciduous forest
	Evergreen	Total percentage evergreen forest
	Mixed forest	Total percentage mixed forest
	Wooded wetlands	Total percentage wooded wetlands
	Herb_wetlands	Total percentage herbaceous wetlands
	Open water	Total percentage open water
	Bare rock	Total percentage bare rock

** not analyzed in current draft

Results

Distribution and status lotic

Brook trout remain in 3,344 subwatersheds and are extirpated from 1,166 subwatersheds of their potential range within the study area (Table 3a. Figure 2). We determined that 5,837 subwatersheds within the potential historic range never had the habitat to have self-reproducing brook trout populations or brook trout were physically isolated from suitable habitat (i.e. waterfalls). Previous distribution ranges included entire watersheds where brook trout were present, even though the distribution may have been limited to only select habitats (i.e. higher elevations) within the watershed (MacCrimmon and Campbell 1969). Brook trout status could not be determined on another 791 subwatersheds because of data deficiencies. Brook trout were known to be absent in another 260 subwatersheds but it was not known if they were extirpated or never occurred in these subwatersheds. In subwatersheds where reproducing populations of brook trout are present 45% were classified as Present: Greatly reduced (i.e. lost over 50% of the habitat supporting reproducing brook trout); 15 % Present: Reduced (i.e. lost between 10% and 49% of habitat supporting reproducing brook trout); 9 % Present: Intact (i.e. lost less than 10% of the habitat supporting reproducing brook trout; and 31 % Present: Qualitative data (i.e. did not have data to determine the % of reproducing habitat lost)(Table 3a).

Brook trout occurred in every state with the percentage of extirpated subwatersheds varying from <1% in Maine and New Hampshire to >40% in the states of Maryland, Tennessee, North Carolina, South Carolina and Georgia (Figure 2, Appendix 2 Figure A2.1 to A2.7). Where present the highest percentage of subwatersheds that had Present: Intact or Present: Reduced (i.e. lost less than 50% of habitat that supported reproducing brook trout) ranged from a high of 38% in Virginia and West Virginia to a low of 3% in the southeastern states of Tennessee, North Carolina, South Carolina and Georgia (Figure 3, Appendix 2 Figure A2.8 to A2.14). The New England states of Maine (68 %) and New Hampshire (70 %) had the highest percentages of watersheds where only qualitative data existed and the percentage of lost reproducing brook trout habitat could not be determined (Figure 3, Appendix 2 Figure A2.8 to A2.14).

Distribution and status lentic

The states of Maine, New York, New Hampshire and Vermont have the most subwatersheds with lentic habitats supporting brook trout (n = 753). The remaining states have no natural coldwater lentic habitats or no longer have coldwater lentic habitats that support reproducing populations of brook trout. It is not known if brook trout are extirpated or that they never occurred in many of the natural lentic habitats from these remaining states. Subwatersheds with intact lentic habitats are found predominately (97%) in the state of Maine (Table 3b). The classification of subwatersheds by lentic habitats may be misleading because of the large number of lakes and ponds in some subwatersheds. Many subwatersheds had individual lakes that were intact but few subwatersheds had all their lakes intact.

Threats lotic

Local expert fisheries biologists provided opinion on threats that have partially or completely eliminated (Level 1: High threat) reproducing populations of brook trout within 4,510 subwatersheds. The distribution of the top 15 threats to brook trout in the eastern United States is found in Appendix 3 Figures A3.1 to A3.15. Overall, increased water temperature (20%), agriculture (15%), urbanization (10%), one or more exotic fish species (7%) and riparian habitat (7%) were the top 5 Level 1 threats. The state rankings of the top Level 1 threats varied by state (Table 4). The top 30 Level 1 threats to lotic populations are summarized in Table 4.

When Level 1 high threats were combined with Level 2 medium threats (threats that have reduced but not eliminated reproducing brook trout populations) agriculture (36%), increased water temperature (35%), sediment from roads (27%), one or more exotic fish species (26%), and urbanization (25%) were the top 5 cumulative threats (Table 5). The top 30 Level 1 and Level 2 threats to lotic populations are summarized in Table 5. The state rankings of the cumulative Level 1 and Level 2 threats varied by state (Table 5).

When Level 1, Level 2 and Level 3 low threats (threats that have not yet eliminated or reduced reproducing brook trout but are a concern) were combined agriculture (43%), sediment from roads (40%), increased water temperature (39%), one or more exotics fish species (38%) and urbanization (33%) were the top 5 cumulative Level 1, 2, or 3 threats (Table 6). The top 30 Level 1, Level 2 and Level 3 cumulative threats to lotic populations are summarized in Table 6. The state rankings of the cumulative Level 1, Level 2 and Level 3 threats varied by state (Table 6).

Summaries of individual states threats by Level 1, cumulative Level 1 and Level 2, and cumulative Level 1, Level 2, Level 3 are summarized in Appendix 3 Tables A1 to A3.

Table 3a. Distribution of brook trout in lotic habitats in subwatersheds in the eastern United States.

State		Status where present				Presence not documented			
	Total Present	Present: Qualitative Data	Present: Intact	Present: Reduced	Present: Greatly Reduced	Never Occurred	Absent	Extirpated	Unknown
ME	969	658	147	76	88	12	0	5	61
NH	242	195	21	13	13	1	0	0	37
VT	203	20	33	64	86	27	0	6	31
MA	144	34	1	29	80	19	4	20	119
RI									
CT	148	2	1	18	127	0	0	29	6
NY	343	106	25	63	149	36	0	129	89
NJ	78	19	1	14	44	667	0	94	76
PA	646	5	16	118	507	72	0	449	218
OH	3	0	0	0	3	71	7	1	0
MD	50	0	3	5	42	175	0	83	12
WV	154	4	4	16	130	283	249	24	7
VA	180	8	36	80	56	836	0	148	64
NC	119	0	0	3	116	1301	0	95	22
SC	7	0	0	0	7	943	0	12	8
TN	36	0	1	2	33	985	0	18	27
GA	22	0	0	0	22	409	0	53	16
Rangewide Totals	3344	1051	289	501	1503	5837	260	1166	793

Table 3b. Distribution of brook trout in lentic habitats in subwatersheds in the eastern United States. States with no data currently have no lentic habitat with brook trout; lentic habitats may not exist or when they exist it is unknown if brook trout have been extirpated or never occurred in these habitats.

State	Total Present	Status where present: Present: Qualitative Data	Present: Intact	Present: Reduced	Present: Greatly Reduced	Presence not documented: Absent	Extirpated	Unknown
ME	632	89	185	35	323	0	7	235
NH	17	0	3	4	10	2	0	250
VT	17	2	1	0	14	1	14	13
MA								
RI								
CT								
NY	87	16	2	11	58	0	14	33
NJ								
PA								
OH								
MD								
WV								
VA								
NC								
SC								
TN								
GA								
Rangewide Totals	753	107	191	50	405	3	37	531

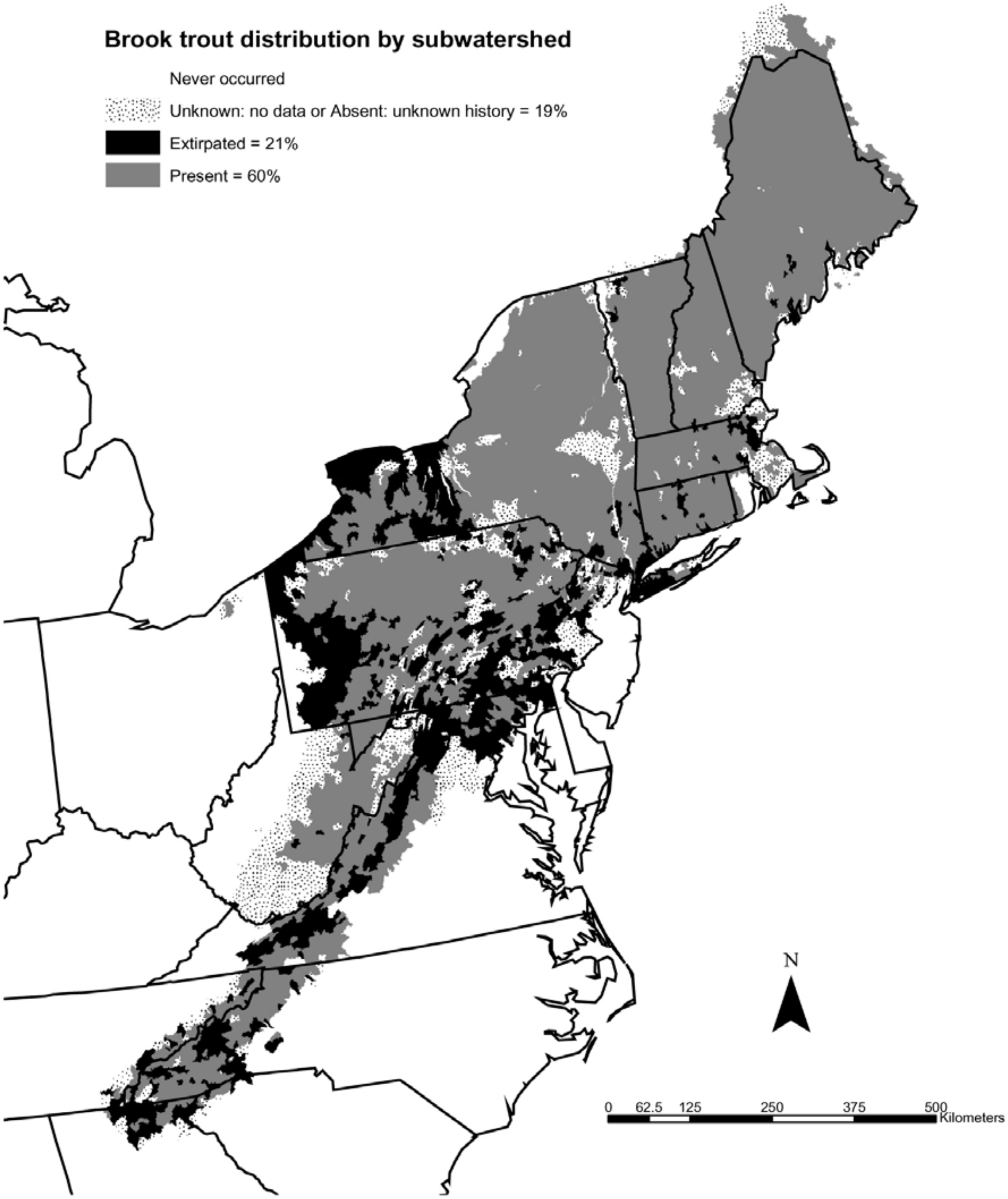

Figure 2. Distribution of subwatersheds in the eastern United States where brook trout are present (60 %), extirpated (21 %) or of unknown status (Unknown: no data and Absent: Unknown history) (19 %). Subwatersheds classified as Never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT

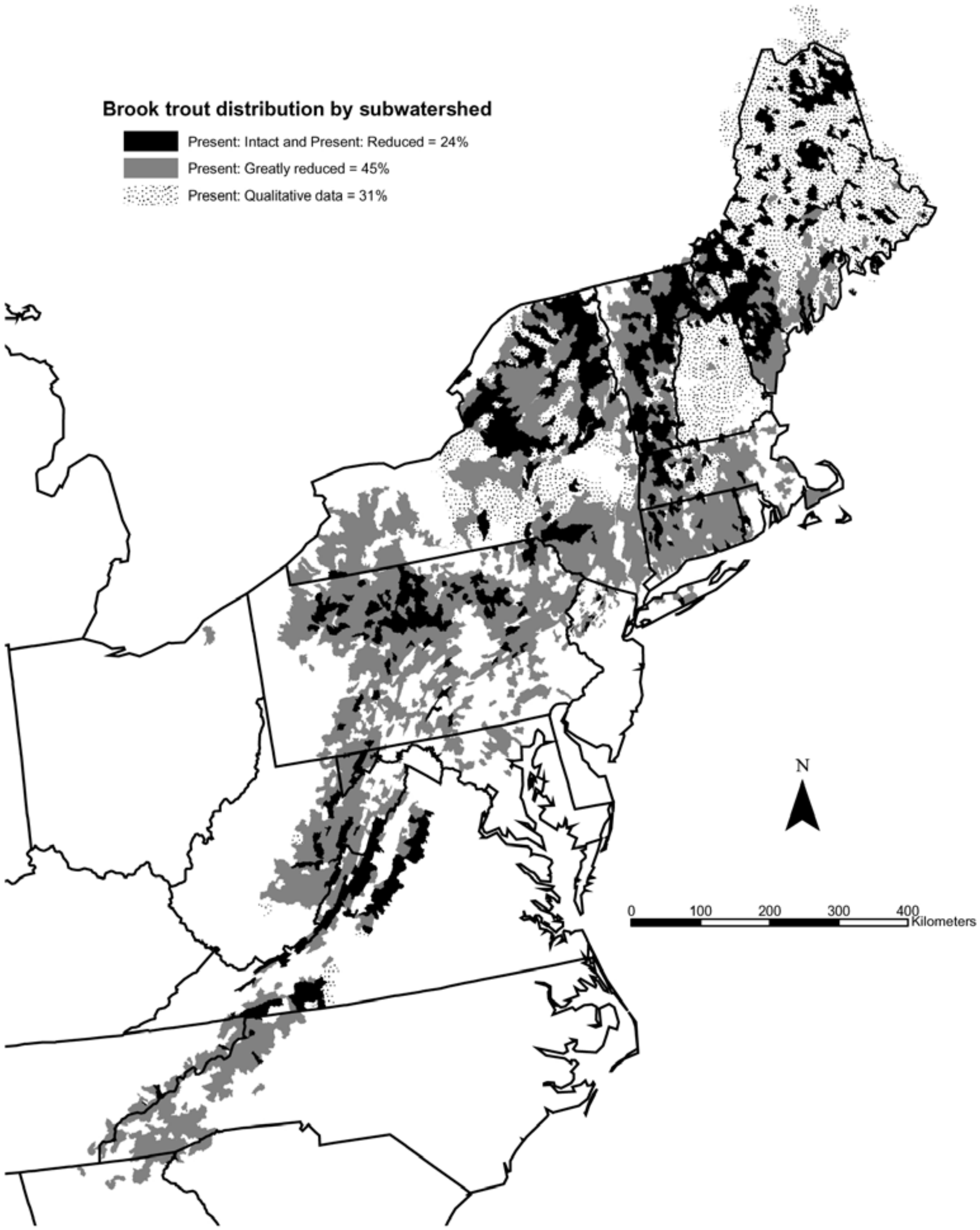

Figure 3. Subwatersheds containing brook trout in the eastern United States. Subwatersheds with Present: Intact and Present: Reduced (24 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (45 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (31 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT.

Threats lentic

Local expert fisheries biologists provided opinion on threats that have partially or completely eliminated (Level 1: High threat) reproducing populations of brook trout within lakes and ponds on 1,324 subwatersheds in the states of Maine, New York, Vermont and New Hampshire, the only states with appreciable amounts of reproducing brook trout lakes and ponds. The state rankings of the top Level 1 threats varied by state (Table 7). Overall, one or more exotic fish species, low pH from acid rain and the specific exotic fish smallmouth bass were the top 3 threats. The top 20 Level 1 threats to lentic brook trout populations are summarized in Table 7.

When Level 1 high threats were combined with Level 2 medium threats (threats that have reduced but not eliminated reproducing lentic brook trout populations) all exotic species, smallmouth bass, other cool/warmwater species, largemouth bass and dissolved oxygen were the top 5 cumulative threats (Table 7.). The top 20 Level 1 and Level 2 threats to lentic populations are summarized in Table 7. In the cumulative rankings of Level 1 and Level 2 threats all states had exotic species in their top 3 threats to lentic populations of brook trout. When Level 1, Level 2 and Level 3 low threats (threats that have not yet eliminated or reduced reproducing brook trout but are a concern) were combined one or more exotic fish species, smallmouth bass and forestry were the top 3 threats (Table 7). The top 20 Level 1, Level 2 and Level 3 cumulative threats to lentic populations are summarized in Table 7. Exotic species and the specific exotic smallmouth bass were ranked 1 and 2 for all states in the cumulative Level 1, Level 2 and Level 3 threats.

Summaries of individual states threats by Level 1, cumulative Level 1 and Level 2, and cumulative Level 1, Level 2, Level 3 are summarized in Appendix 3 Table 4.

Pilot Study Mid-Atlantic Highlands

Because of the small sample sizes in some of the classifications (i.e. Present: Intact) we grouped the classifications of subwatersheds into three groups for logistic regression analysis: Group 1 (Extirpated)(n = 792); Group 2: (Present greatly reduced)(n = 779); and Group 3: (subwatersheds classified as; Present: Intact (both large and small) and Present: Reduced)(n = 292). The logistic regression examined all possible paired comparisons among the three groups: Group 1 (100% loss); Group 2 (> 50% loss) and Group 3 (<50% loss). The single metric variables have a lower overall prediction rate but have the advantage of indicating specific land use metric thresholds to natural resource managers. Because of the interdependence of the various metrics in the multi-metric models it is difficult to determine thresholds. In the single metric model the threshold cutoff of an individual metric can be changed depending on which Group needs to be predicted correctly. Although the means of many metrics were significantly different among the three groups the best single metric for predicting pairings of the three groups correctly was the percentage of human land use within the entire subwatershed (ANOVA, $F = 317$, $p < 0.001$). For this reason we concentrated on the percentage of human land use in the subwatershed for all single metric models. A square root transformation was used to normalize the data. The range of conditions for the percentage of human land use for all subwatersheds and the three classification groups is found in Figure 4 and 5.

Models predicting Group 1 from Group 3

Several single and multi-metric models correctly predicted Group 1 from Group 3 at a high rate. In the single metric model a cutoff of 11% total human land use had an overall correct prediction rate of 81% (97% correct prediction of Group 1 and 38% correct prediction of Group 3). A cutoff of 18% human land use had an overall correct prediction rate of 80% (88 % correct prediction of Group 1 and 61% correct prediction of Group 3). A four metric model using the % total human land use, % evergreen forest, % deciduous forest in the water corridor, and the % mixed forests in the water corridor increased the overall prediction rate to 88 % (94 % correct on Group 1 and 71 % correct on Group 3). Another four metric model using the % total human land, road density, road density within the water corridor, and the road/stream crossing density per stream kilometer had an overall correct prediction rate of 86 % (92 % correct on Group 1 and 67 % correct on Group 3.

Models predicting Group 1 from Group 2

The second most accurate models were comparing Group 1 to Group 2. In the single metric model a cutoff of 30 % total human land use had an overall correct prediction rate of 69 % (72 % correct prediction of Group 1 and 67 % correct prediction of Group 2). An eleven metric model (% forest, % evergreen forest, % evergreen forest in the water corridor, % forest in the water corridor, % row crops, % high residential use, road density, % mines, % quarries/gravel pits, % transitional habitat and subwatershed size) increased the overall prediction rate to 78% (82 % correct on Group 1 and 74 % correct on Group 3).

Models predicting Group 2 from Group 3

The least accurate models were those separating Group 2 from Group 3. In the single metric model a cutoff of 12 % total human land use had an overall correct prediction rate of 61 % (67 % correct prediction of Group 2 and 45 % correct prediction of Group 3). A six metric model using the road density within the water corridor, % low residential use, % mines in the subwatershed, % mixed forests, % row crops, and % of wooded wetlands increased the overall prediction rate to 70 % (71 % correct on Group 2 and 66 % correct on Group 3).

Discussion

We evaluated brook trout at the subwatershed level in the eastern United States an area that comprises approximately 25 % of the species native range and 70 % of the species native range in the United States (MacCrimmon and Campbell 1969). Brook trout are not currently threatened with extinction across the entire range but 48 % of the subwatersheds in our study area were either extirpated (21 %) or greatly reduced (27 %). Many of the subwatersheds that were greatly reduced only had one or two small populations of brook trout restricted to isolated headwater habitats. These subwatersheds lacked the redundancy and connectivity to reestablish populations and they are especially prone to extirpation from increased human land use impacts or natural stochastic events.

Many of these extirpations and reductions in habitat supporting brook trout have occurred at the turn of the century from historic logging and agricultural practices. Over 75,000 dams (USCOE 1998), 2 million miles of roads (Navtech 2001) and an increase of 90 million residents (U.S. Census Bureau 2002) have also occurred in the study area over the last 100 years. This has lead to dramatic land use changes where now the average subwatershed has over 30 % land uses characterized as human impacts (USGS 2002a). This last 100 years has also been a period of dramatic changes in fish distributions through intended and unintended stockings and the subsequent naturalization of both coldwater and warmwater fishes. Many of these stockings and subsequent naturalizations occurred in lakes and streams that previously were predominately brook trout. However, impacts are just not from the past and the databases used in the study and the expert opinions of the biologists consulted showed many subwatersheds to have recent losses (last ten years) of reproducing populations of brook trout. Many of the threats identified by biologists, with the exception of exotic fish species, fall into the general category of land use changes.

Table 4. Summary of the expert opinion of the top 30 stream Category 1 high level threats for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 threats (duplicate numbers indicate ties in rankings).

Rank	**Threats:**	**TOT#**	**ME**	**NH**	**VT**	**MA**	**RI**	**NY**	**CT**	**NJ**	**PA**	**OH**	**WV**	**VA**	**MD**	**NC**	**SC**	**TN**	**GA**
1	Water temp – high	883	1	3	1	2		1	2	3	1	1		1	1			3	
2	Agriculture	689						3	5		2		1	2	2				3
3	Urbanization	438	1		5	3			3	2	5	2			3			5	
4	All exotics	418		2				5		4				4		1		1	1
5	Riparian habitat	318						2			4					5			
6	Rainbow trout	307		4										5		2		2	1
7	Historic forestry	304							1						5	4			
8	Dams (inundation)	302	3	1	2	1				1		2							
9	Grazing	286												3					4
10	Brown trout	235		4						4						3		4	5
11	In stream/lake habitat	199		4	4	4						4							
12	Low pH -Acid mine drainage	180									3		2						
13	Sediment – roads	156							4										
14	Low pH -Acid rain	113											4						
15	Minimum flow	90			3	5													
16	Historic agriculture	88													4				
17	Eutrophication	82	4																
18	Mining	77											3						
19	Beavers	64						4											
20	Stream fragmentation (roads)	62										4							
21	Forestry	48											4						
22	Historic grazing	39																	
23	Pesticides	26												5					
24	Surface water withdrawals	24																	
25	Heavy metals	18																	
26	Recreation	16		4															
27	Ground water withdrawals	12																	
28	Floods	10																	
29	Dissolved oxygen	6																	
30	Turbidity	6																	

Table 5. Summary of the expert opinion of the top 30 cumulative stream Category 1 high level threats and Category 2 medium level threats for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 threats (duplicate numbers indicate ties in rankings).

Rank	Threats:	TOT#	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA
1	Agriculture	1610	3		4			4			1		1	4	3	5		3	
2	Water temperature – high	1557		2		1		1		4		1		2	1				
3	Sediment – roads	1215		5	3	3	2	2	1	1								3	4
4	All exotics	1162		3	5			2			3	5				1		1	1
5	Urbanization	1129							3	2					2	4		5	5
6	Riparian habitat	1000			3	4						5	5	3		3			
7	Brown trout	853						3			4								
8	Stream fragmentation (roads)	767	5			2				5		2		1					
9	Dams (inundation)	696	2	5		1			5	3		2							
10	Forestry	642	4										2						
11	Historic forestry	616			2				2			5							3
12	In stream/lake habitat	573				5													
13	Grazing	542												5					
14	Rainbow trout	489										5				2		2	1
15	Beavers	358	1					5											
16	Eutrophication	307																	
17	Low pH –Acid rain	305		1									3						
18	Minimum flow	299																	
19	Mining	261																	
20	Low pH –Acid mine drainage	227											4						
21	Turbidity	216																	
22	Ground water withdrawals	165													4				
23	Historic agriculture	164																	
24	Pesticides	142																	
25	Surface water withdrawals	129													5				
26	Historic Sediment - roads	107			5														
27	Smallmouth bass	106																	
28	Floods	87		4								5							
29	Recreation	84										5							
30	Bird predation	54																	

Table 6. Summary of the expert opinion of the top 30 cumulative stream Category 1 high level threats, Category 2 medium level threats and Category 3 low level threats for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 threats (duplicate numbers indicate ties in rankings).

Rank	Threats:	TOT#	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA
1	Agriculture	1959						3			1		1	3	3			3	5
2	Sediment – roads	1799	2	2	1	2			4	3		1			4			3	4
3	Water temperature – high	1769			5			1	2	4	2	1		4	2				
4	All exotics	1694	4	1	4			2			3					1		1	1
5	Urbanization	1482	5	5					1	1	5	1			1	3		5	
6	Riparian habitat	1288			2	3			2				5	2		4			
7	Forestry	1241	1										2						
8	Brown trout	1212		4				4			4					5			
9	Stream fragmentation (roads)	992				4				5		1		1					
10	Dams (inundation)	846				1				3									
11	In stream/lake habitat	739							5			1							
12	Historic forestry	705			2														3
13	Beavers	682	3					5											
14	Grazing	646												5					
15	Rainbow trout	623		3												2		2	1
16	Minimum flow	402				5													
17	Eutrophication	395																	
18	Low pH -Acid rain	359											3						
19	Mining	282																	
20	Smallmouth bass	280																	
21	Turbidity	249																	
22	Low pH -Acid mine drainage	240											4						
23	Ground water withdrawals	224																	
24	Historic agriculture	216																	
25	Surface water withdrawals	214													5				
26	Pesticides	202																	
27	Recreation	146																	
28	Floods	131																	
29	Forest pests and disease	115																	
30	Historic Sediment - roads	107																	

Table 7. Summary of the expert opinion of the top 20 lake and pond threats (Category 1 , cumulative Category 1 and 2, cumulative Category 1,2 and 3) for subwatersheds (n = 1,294) within the brook trout range in the eastern United States. State values are rankings of the top 5 threats (duplicate numbers indicate ties in rankings).

Lakes and Ponds Category 1 Threat	**ME Rank**	**VT Rank**	**NY Rank**	**TOT #**	**Rank**	**Lakes and Ponds Categories 1+2 Threats**	**ME Rank**	**VT Rank**	**NY Rank**	**TOT #**	**Rank**	**Lakes and Ponds Categories 1+2+3 Threats**	**ME Rank**	**VT Rank**	**NY Rank**	**TOT #**
All exotics	1	2	2	**32**	1	All exotics	1	1	1	**316**	1	All exotics	1	1	1	**416**
Low pH -Acid rain			1	**20**	2	Smallmouth bass	2	2	2	**183**	2	Smallmouth bass	2	2	2	**264**
Smallmouth bass	2		4	**19**	3	Other cool/warmwater exotics	3	3	3	**174**	3	Forestry	3	3	5	**227**
Other cool/warmwater exotics	5	2	3	**19**	4	Largemouth bass	4			**128**	4	Other cool/warmwater exotics	4	3	3	**193**
Northern pike	4			**11**	5	Dissolved oxygen	5			**54**	5	Largemouth bass				**136**
Largemouth bass	3			**10**	6	Eutrophication				**47**	6	Sediment – roads	5			**133**
Dams (inundation)		1		**7**	7	Forestry		4	5	**40**	7	Dissolved oxygen				**83**
Brown trout				**6**	8	Water temperature – high				**33**	8	Water temperature – high				**59**
Rainbow trout			5	**4**	9	Brown trout				**33**	9	Urbanization				**55**
Dissolved oxygen				**3**	10	Northern pike				**30**	10	Eutrophication				**47**
Forestry				**2**	11	Low pH -Acid rain			4	**22**	11	Brown trout				**46**
Eutrophication				**2**	12	Rainbow trout				**20**	12	Agriculture		5		**43**
Urbanization				**1**	13	Agriculture		4		**19**	13	Beavers				**43**
Historic forestry				**1**	14	Dams (inundation)				**13**	14	Landlocked salmon				**36**
Water temperature – high				**1**	15	Landlocked salmon				**13**	15	Northern pike				**30**
Heavy metals				**1**	16	Urbanization				**11**	16	Other coldwater exotics				**29**
Landlocked salmon				**1**	17	Other coldwater exotics				**11**	17	Low pH -Acid rain			4	**23**
Walleye				**1**	18	Beavers				**10**	18	Dams (inundation)				**17**
Over fishing – legal				**1**	19	Lake trout				**8**	19	Lake trout				**17**
Beavers				**1**	20	Walleye				**8**	20	Turbidity				**16**

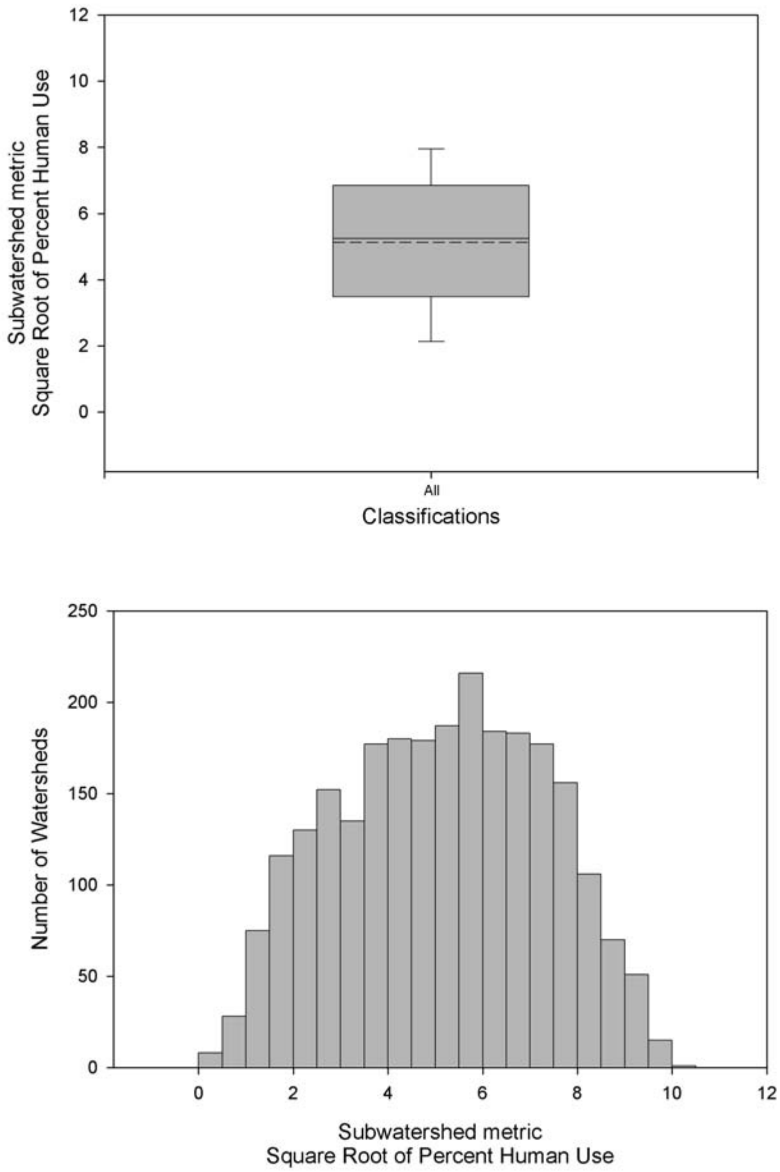

Figure 4. Distribution of the percentage of total human uses by subwateshed (N = 4,484)

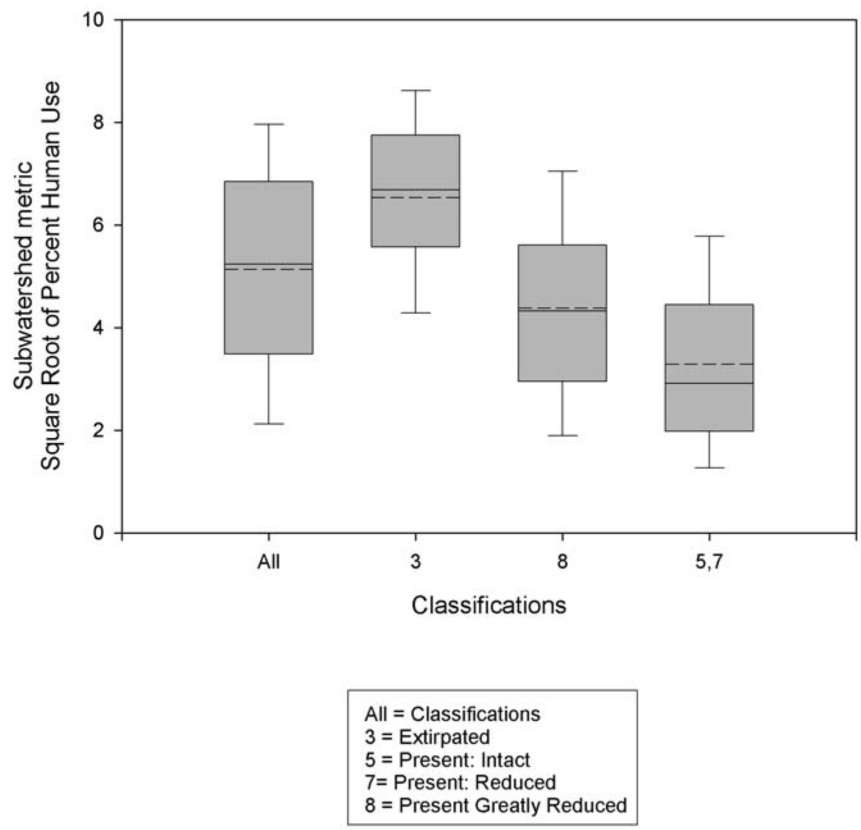

Figure 5. Distribution of the percentage of total human land uses by brook trout classification category.

Our pilot study in the Mid-Atlantic region shows human land uses to be important factors in predicting brook trout status at the subwatershed level. Similar to large scale assessments of salmonids in the western United States (Reiman et al. 1997) we suggest future changes in brook trout distribution and status in the study area will be driven by increases in human land use practices, the expansion of exotic fishes, and existing and future habitat fragmentation.

Many subwatersheds (33 %) had inadequate monitoring (either no data, data older than 10 years old, or only qualitative presence/absence data) to assess the status of brook trout for the purposes of this study. Increased sampling in these subwatersheds will be needed to evaluate and monitor land use changes and the spread of exotic species. Many of these subwatersheds occurred in the New England states of Maine and New Hampshire, which are relative brook trout strong holds. Increased monitoring of the status of brook trout should be a priority for long-term conservation efforts.

We reviewed all existing databases but limited the use of data older than ten years. Most of the data provided by state and federal agencies had not been published and subject to peer review and in spite of criteria provided for classification there was an element of subjectivity. It is impossible to generate a comprehensive review without such data (Reiman et al. 1997). We attempted to limit errors, reduce subjectivity and provide consistency from unpublished data by using; consistency rules, data standards (quality and age), development of broad classification categories ("no brainers"), and a standard validated procedure with experts.

Key Findings

1. Brook trout have been extirpated from 21 % of the subwatersheds and reduced to small headwater habitats in another 27%. The majority of historic large riverine brook trout habitats no longer support reproducing populations.
2. States below the Mid-Atlantic region (SC,NC,TN,GA) have lost almost all Present: Intact populations.
3. Important data gaps in quantitative data for stream populations exist in many subwatersheds (33%). Large portions of Maine, New Hampshire, New York and smaller portions of Vermont, Massachusetts and West Virginia need increased quantitative monitoring.
4. Experts identified agriculture and urbanization as the top 2 threats to stream populations of brook trout.

5. Land use practices are a useful predictor of brook trout status in streams at the subwatershed scale in the Mid-Atlantic region.
6. Lentic brook trout populations have all but been eliminated except for a few strongholds in the state of Maine. These stronghold populations are extremely vulnerable to the introduction of exotic fish species.
7. Experts identified exotic fish species as the top threat to lake populations of brook trout.

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Appendix A1. Brook trout Population Classification Key: (Lotic habitats)

1a. No quantitative or qualitative databases are available to evaluate presence or absence of historic and/or current naturally reproducing brook trout in the 6th level sub-watershed.
Classification 1.0 (Unknown).
1b. Quantitative or qualitative databases exist that document presence or absence of reproducing populations of brook trout; **go to question 2**

2a. Quantitative and /or qualitative databases document that there are no reproducing brook trout populations today, it is unknown if brook trout populations ever occurred or they have been extirpated. **Classification 1.1 (Absent: Unknown history).**
2b Historic or current databases document the historic range of reproducing brook trout populations; **go to question 3**

3a. Quantitative and/or qualitative databases support that naturally reproducing brook trout historically never occupied habitat or no lotic habitat exists within the 6th level sub- watershed. **Classification 2.0 (Never occurred).**
3b. Based on quantitative or qualitative databases brook trout historically occupied suitable habitat within the 6th level sub- watershed; the presence of reproducing cold water exotics (i.e. rainbow trout, brown trout) within the historic native range of brook trout (McCrimmon and Campbell 1969) indicate brook trout should have been there **go to question 4**

4a. Based on quantitative or qualitative databases historic natural reproducing brook trout populations or fisheries existed but none are currently present within the 6th level sub-watershed today. **Classification 3.0 (Populations extirpated).**
4b. Based on quantitative or qualitative databases brook trout populations (historically naturally reproducing, currently naturally reproducing) exist within the 6th level sub-watershed; **go to question 5.**

5a. Brook trout data quality is presence/absence only (no numbers per unit area or catch per unit effort) or is outside the 6th level sub-watershed, or the data is quantitative but greater than 10 years old), not enough data to determine the percentage of lotic habitats lost. **Classification 4.0** (**Populations present);**
Classification 4.1 (Populations present outside of historic range or previously fishless areas within the range).
Classification 4.5 (Populations presumed to be large and strong (data > 10 years old or no data available)).
5b. Available data meets the following criteria for quality (brook trout per unit area or catch per unit effort data), resolution (has been collected in the 6th level sub-watershed and not expanded from data outside the watershed) and age (less than 10 years old): **go to 6**

6a. Greater than 90% of historic occupied lotic habitats within the entire 6th level sub-watershed support naturally reproducing brook trout populations; **go to question 7**

6b. Greater than 10% of historic populations or fisheries extirpated within the entire 6th level watershed; **go to question 8**

7a. One or more connected brook trout populations within the 6th level sub-watershed support over 5,000 individuals or 500 adults. (Usually characterized by large intact connected habitats (>3 miles). **Classification 5.0** (**Present: Intact large).**
7b. All connected brook trout populations support less than 5,000 individuals or 500 adults; (Usually characterized by small intact isolated habitats (< 3 miles). **Classification 6.0** (**Present: Intact small).**

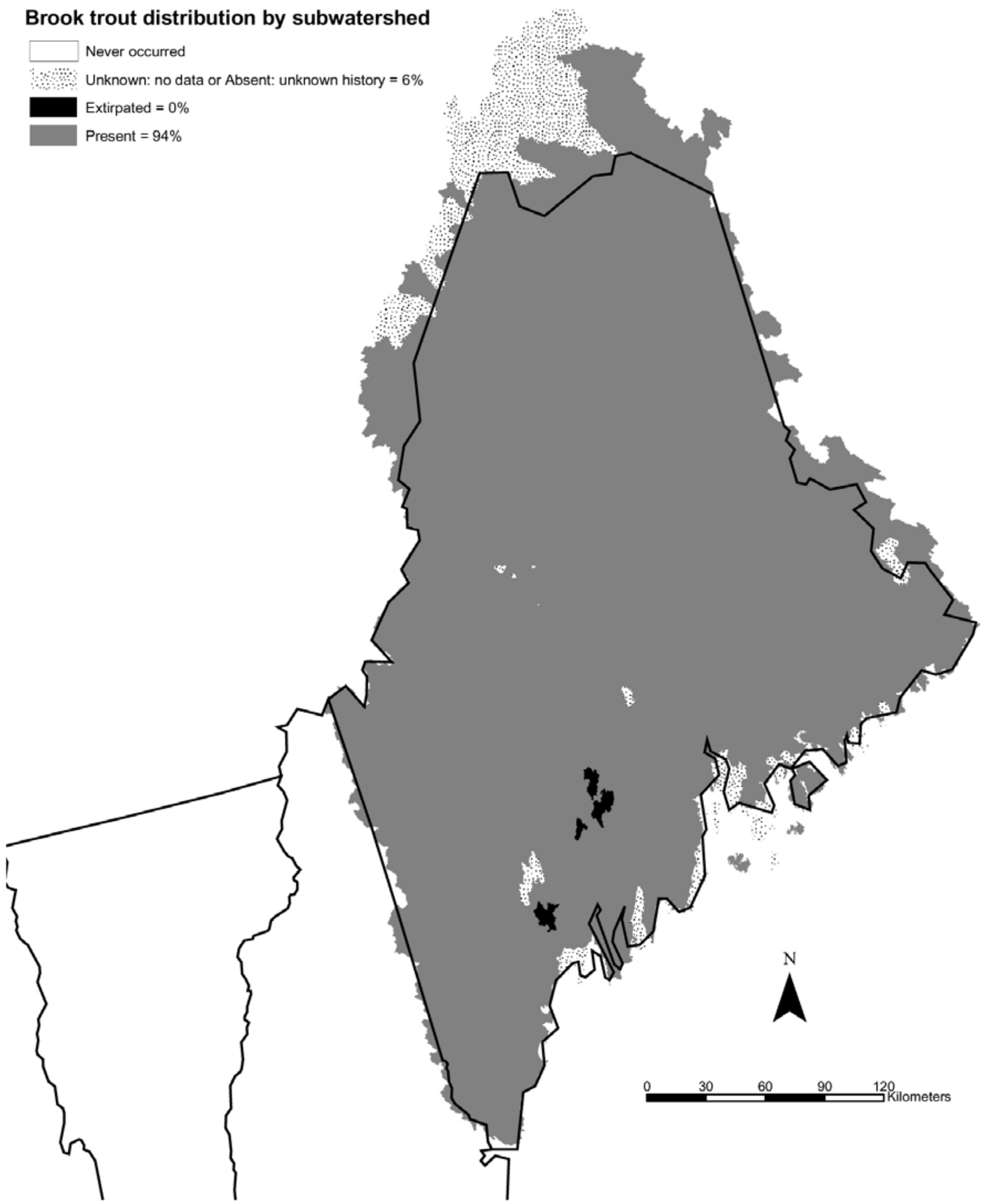
8a. Between 50% and 90% of historic occupied lotic habitats within the entire 6th level sub-watershed support naturally reproducing brook trout populations; **Classification 7.0 (Present: Reduced).**
8b. Between 1% and 49% of historic occupied lotic habitats within the entire 6th level sub-watershed support naturally reproducing brook trout populations; **Classification 8.0 (Present: Severely reduced).**

* Quantitative databases include: A database where methods (electrofishing, snorkeling, gill nets, creel surveys, trap nets, piscides, explosives, etc.) record brook trout numbers per unit area, per unit time, or per gear unit effort and are used directly or in a classification system derived from quantitative data. Does not include modeled, predictive or expanded brook trout numbers where no brook trout have actually been captured or seen within the 6th level HU.

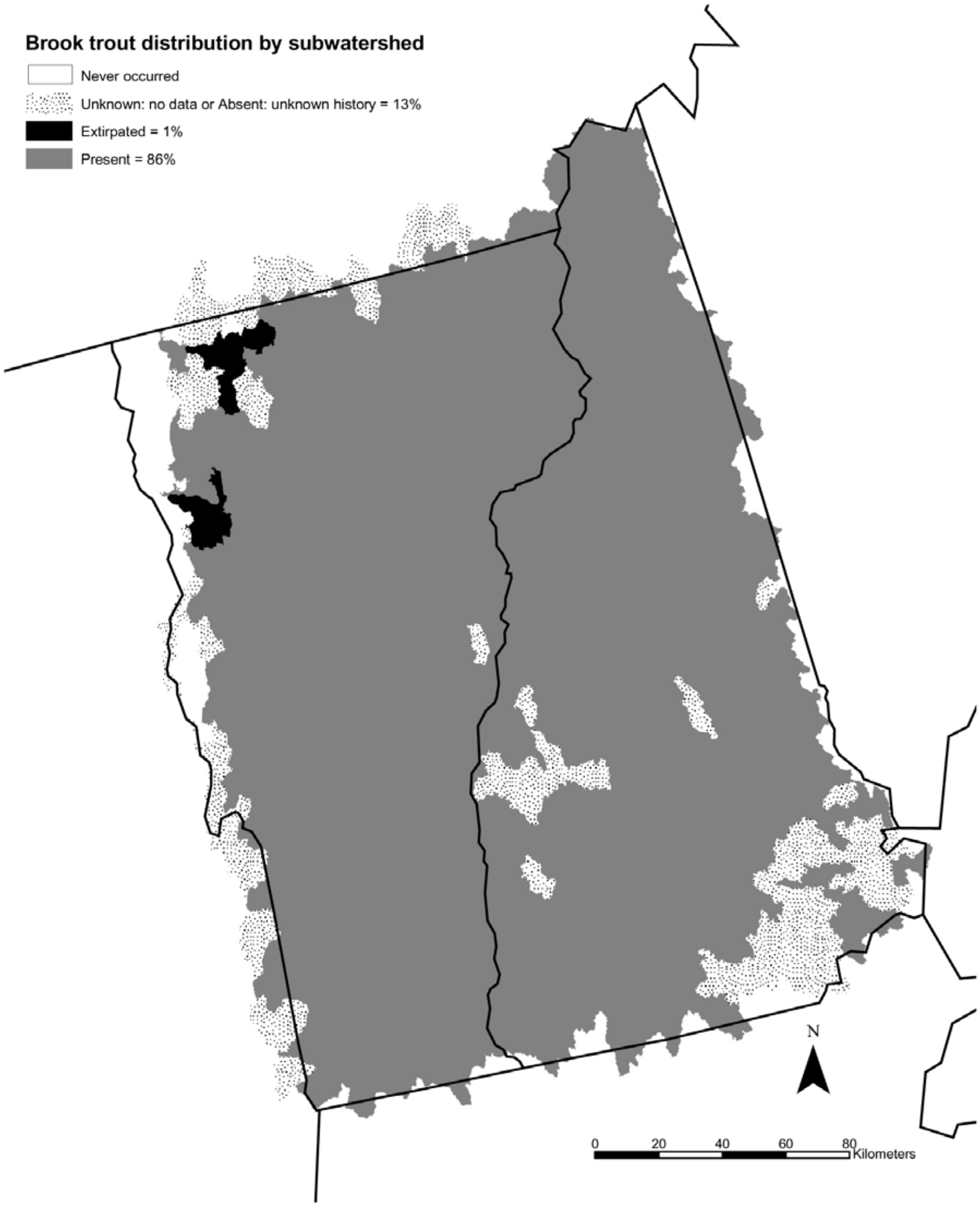
1. Documented loss of reproducing populations by current or historical data
2. Only exotic coldwater species naturally reproducing within native range of brook trout
3. Coldwater exotic species greater than 75% of coldwater biomass or numbers
4. Brook trout carrying capacity reduced by greater than 90% from historic or reference data within the watershed.
5. Reproducing brook trout stream inundated by dam and converted to warm water habitat
6. Acid mine drainage, acid rain, etc. eliminated habitat.
7. Channelization
8. Riparian changes documented by water temperature increases converting to warm water/ cool water.

Appendix A1 Table 2. Limiting factor classifications of brook trout watersheds. **<u>Score all that apply</u>** as: (1) high impact eliminating one or more life cycle components; (2) medium impact reducing but not eliminating life cycle component; (3) low; impact of concern but currently not at threshold to eliminate life cycle component or reduce population. If impacts are historic and no longer are applicable follow the score with the letter (i.e. 1H, 2H, 3H). Note by definition there should be no (1) or (2) limiting factors marked for watersheds classified as Population present: large strong population; or Population present: small strong population. When multiple factors contribute to elimination of one or more life cycle components mark all as (1).

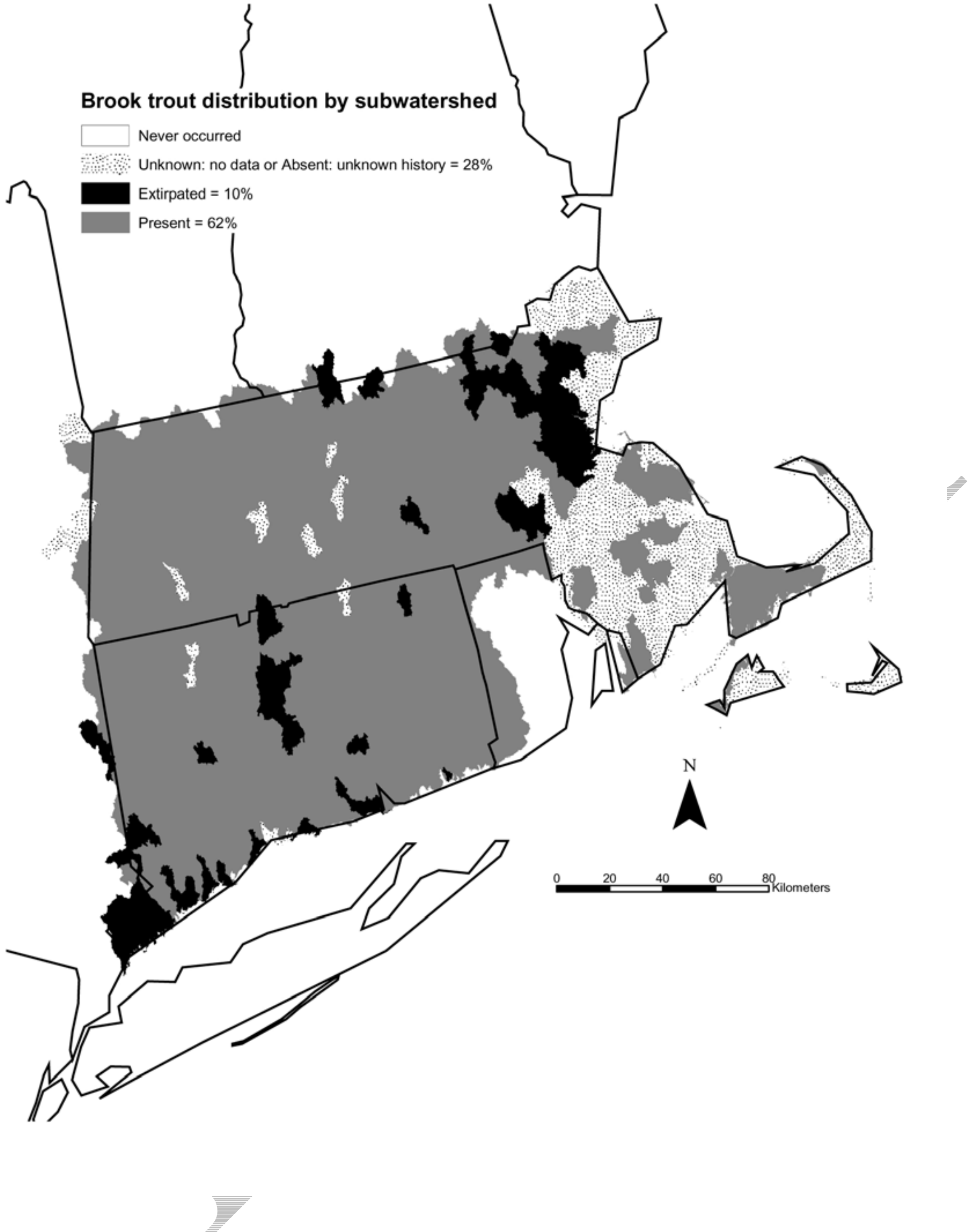
Watershed code:	Lotic Habitats	Lentic habitats
Physical		
Minimum flow		
Surface water withdrawals		
Ground water withdrawals		
Floods		
Debris flows		
Stream fragmentation dams		
Stream fragmentation (road crossings, culverts)		
In stream/lake habitat		
Riparian habitat		
Sediment – roads		
Non-road sediment		
Agriculture		
Urbanization		
Forestry		
Recreation		
Grazing		
Mining		
Chemical		
Low pH -Acid rain		
Low pH -Acid mine drainage		
Dissolved oxygen		
Water temperature – high		
Water temperature – low		
Eutrophication		
Gas super saturation		
Turbidity		
Heavy metals		
Pesticides		
Biological		
Exotics- cold water		
Rainbow trout		
Brown trout		
Lake trout		
Landlocked salmon		
Other____________		
Exotics cool/warm water		
Smallmouth bass		
Largemouth bass		
Walleye		
Northern pike		
Other___________		
Aquatic weeds		
Over fishing – legal		
Poaching		
Forest pests and disease		
Disease (red mouth, whirling disease, furunculosis)		
Beavers		
Bird predation		



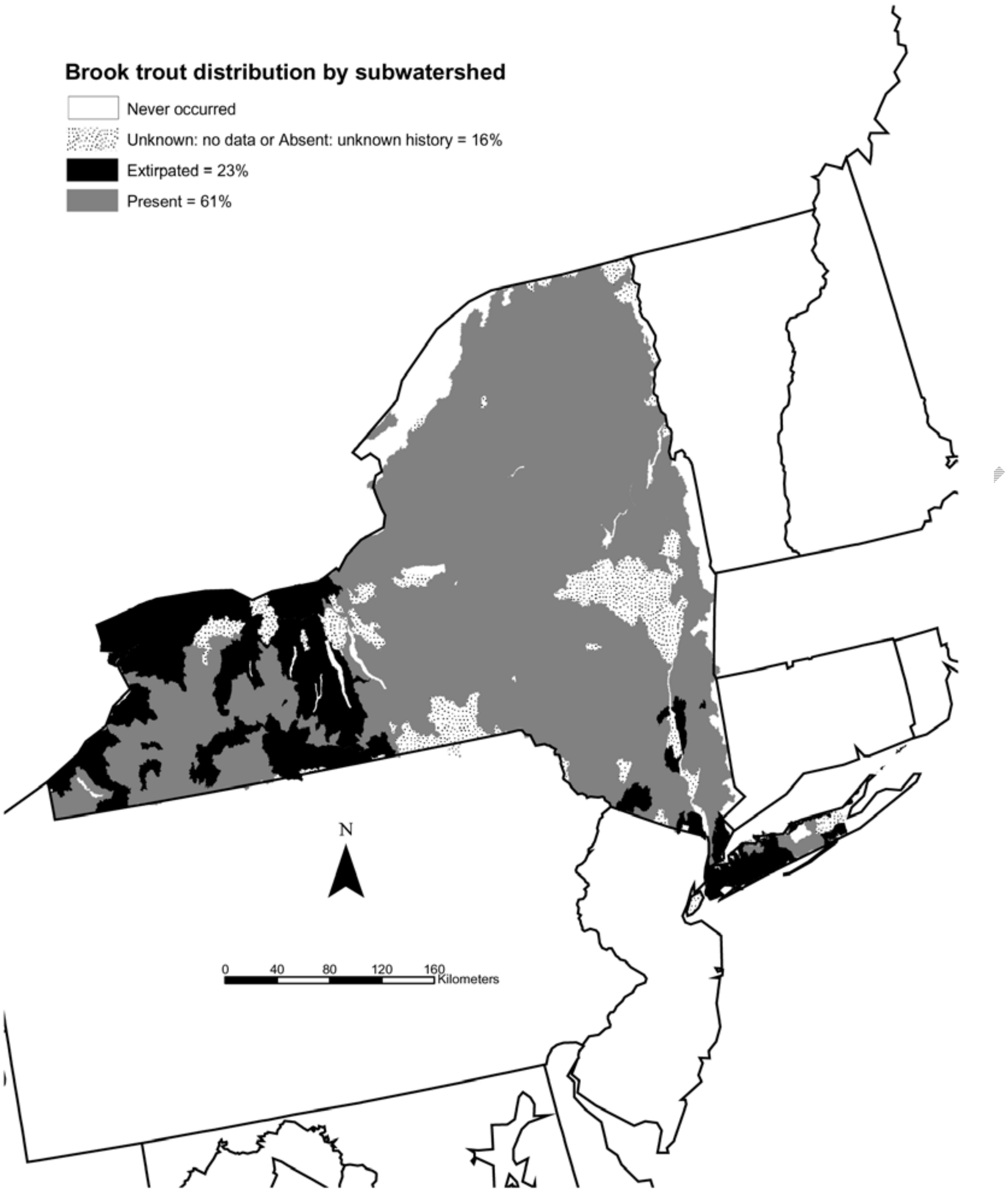
Appendix 2 Figure A2.1. Distribution of subwatersheds in the Maine where brook trout are present (94 %), extirpated (0 %) or of unknown status (Unknown: no data and Absent: Unknown history) (6 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



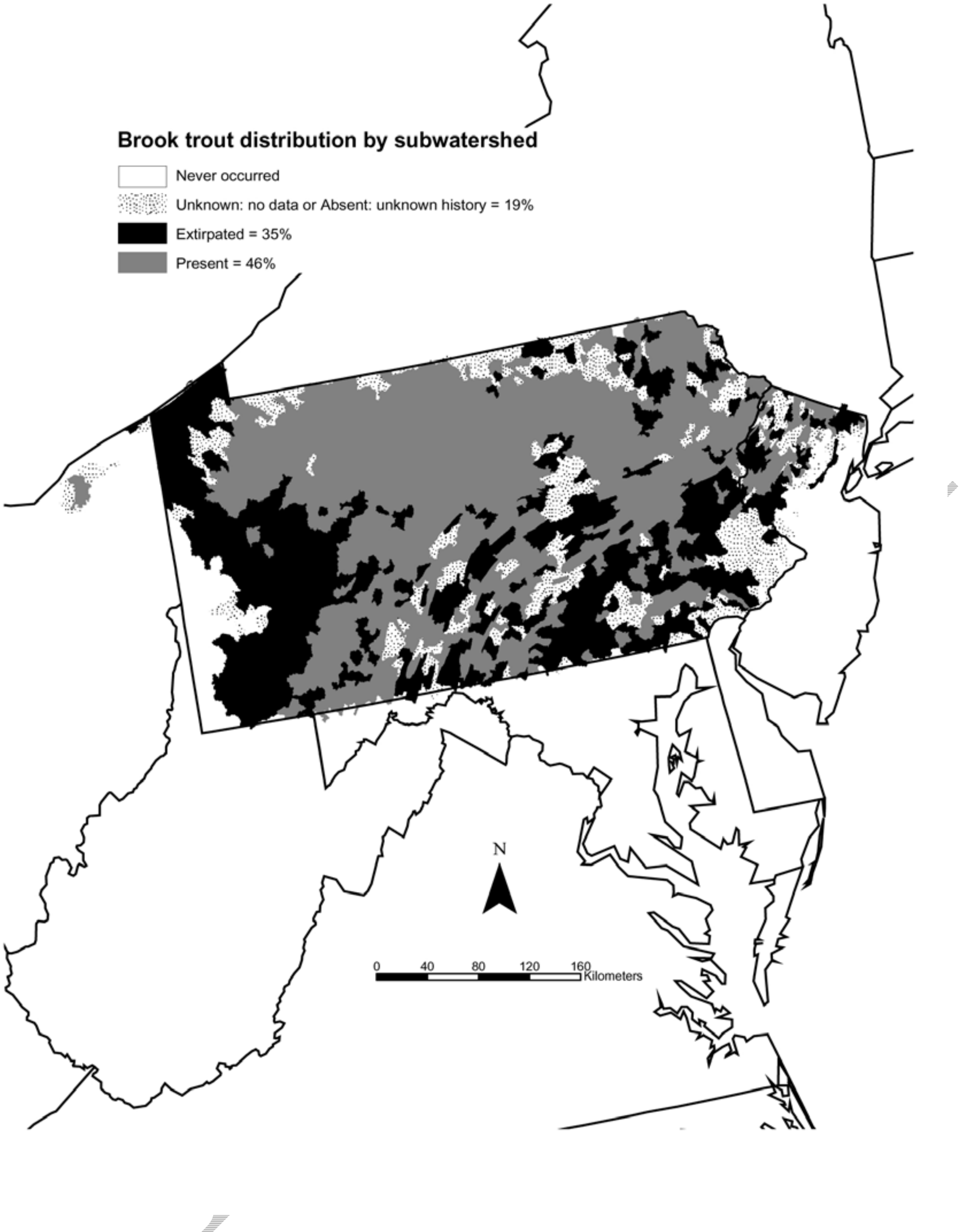
Appendix 2 Figure A2.2. Distribution of subwatersheds in New Hampshire and Vermont where brook trout are present (86 %), extirpated (1 %) or of unknown status (Unknown: no data and Absent: Unknown history) (13 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



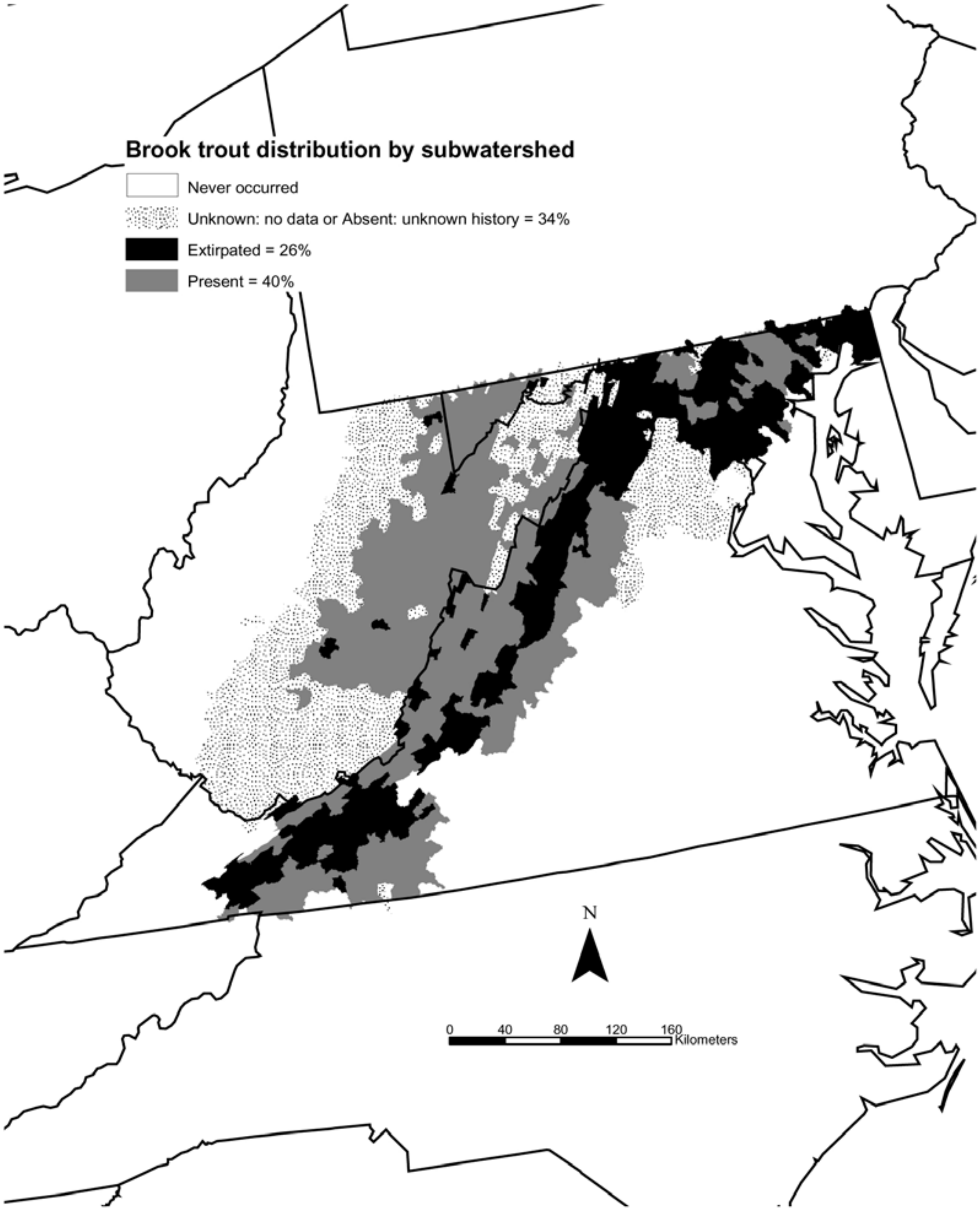
Appendix 2 Figure A2.3. Distribution of subwatersheds in Massachusetts, Connecticut, and Rhode Island where brook trout are present (62 %), extirpated (10 %) or of unknown status (Unknown: no data and Absent: Unknown history) (28 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



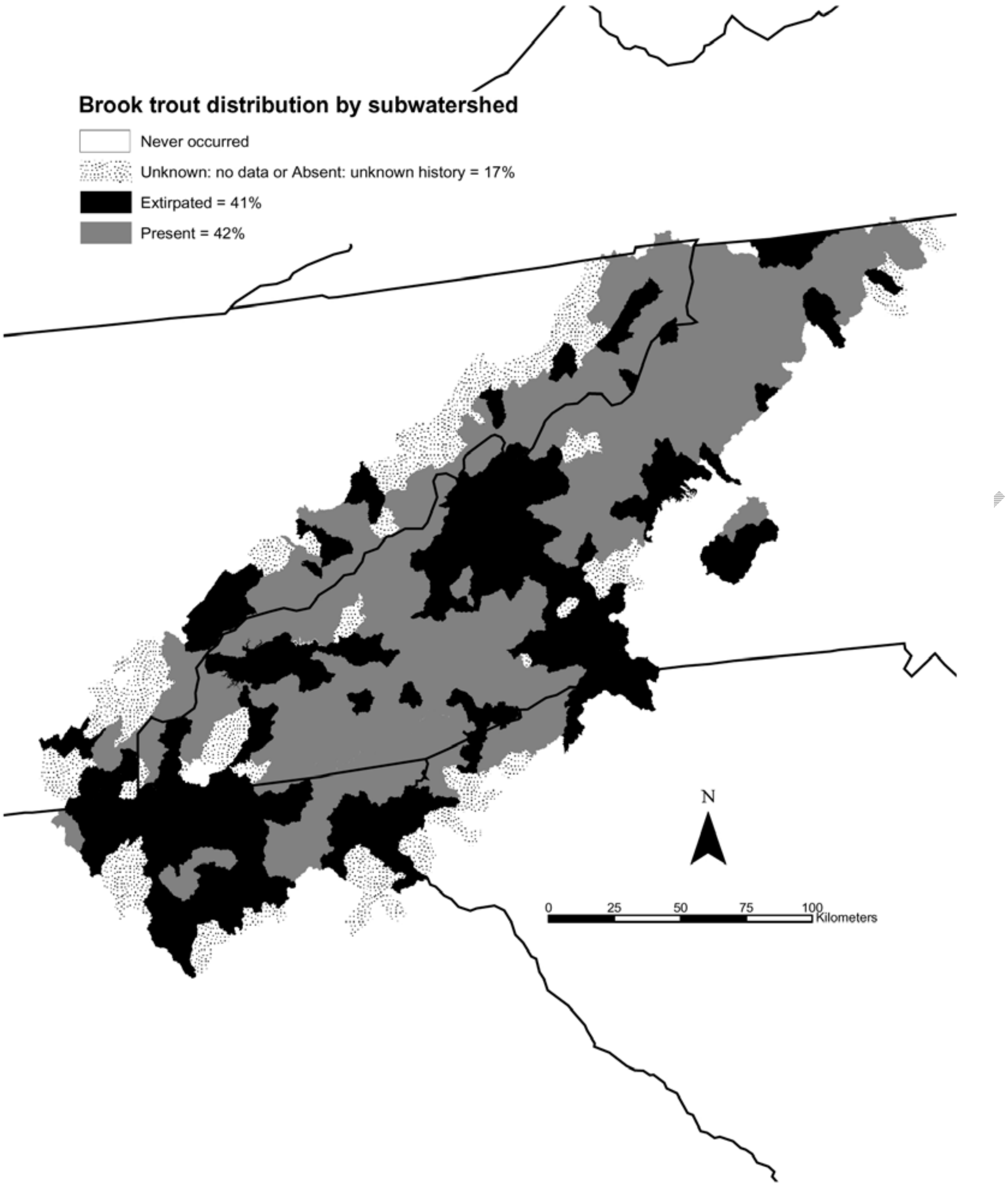
Appendix 2 Figure A2.4. Distribution of subwatersheds in New York where brook trout are present (61 %), extirpated (23 %) or of unknown status (Unknown: no data and Absent: Unknown history) (16 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



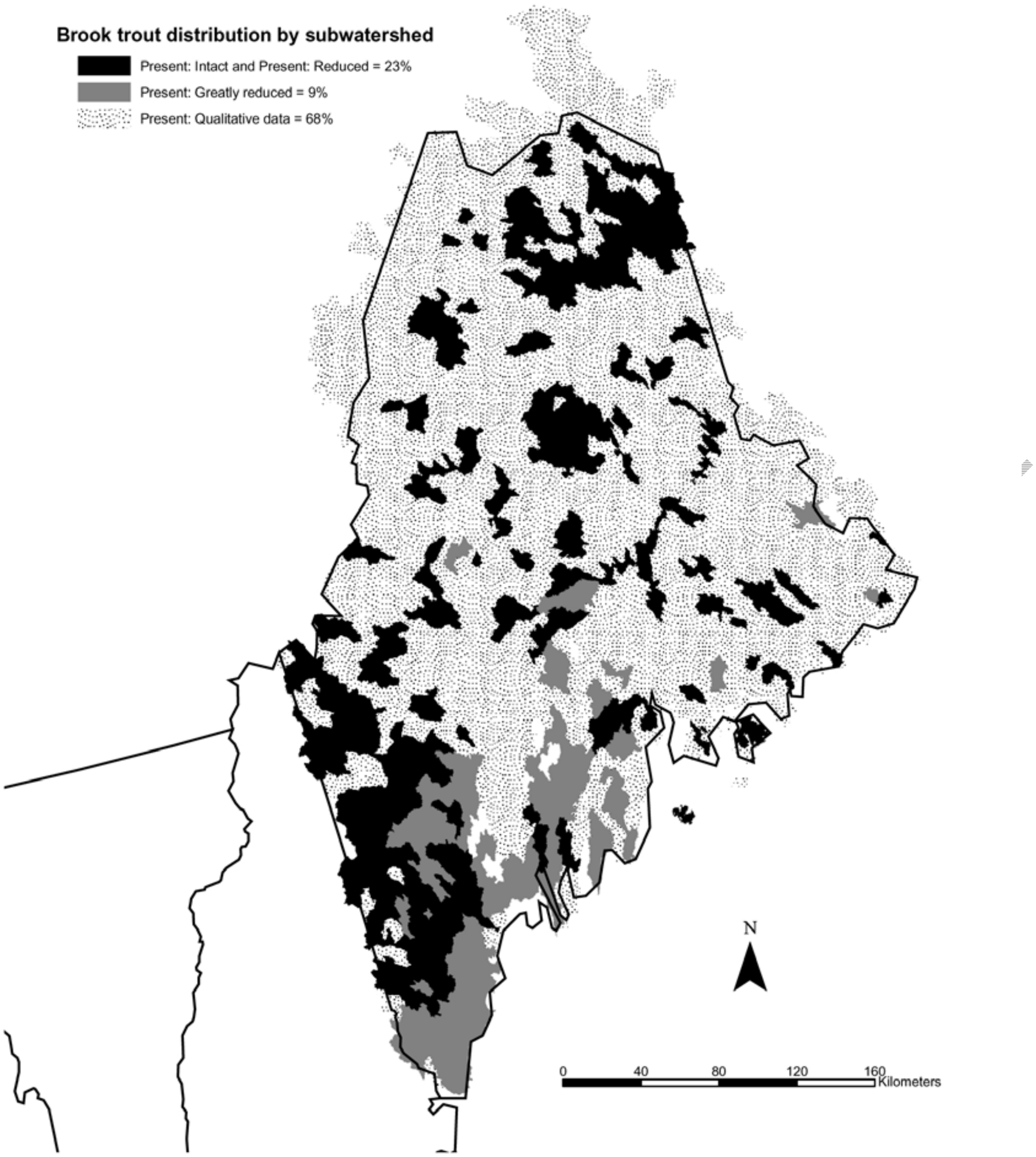
Appendix 2 Figure A2.5. Distribution of subwatersheds in Pennsylvania and New Jersey where brook trout are present (46 %), extirpated (35 %) or of unknown status (Unknown: no data and Absent: Unknown history) (19 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



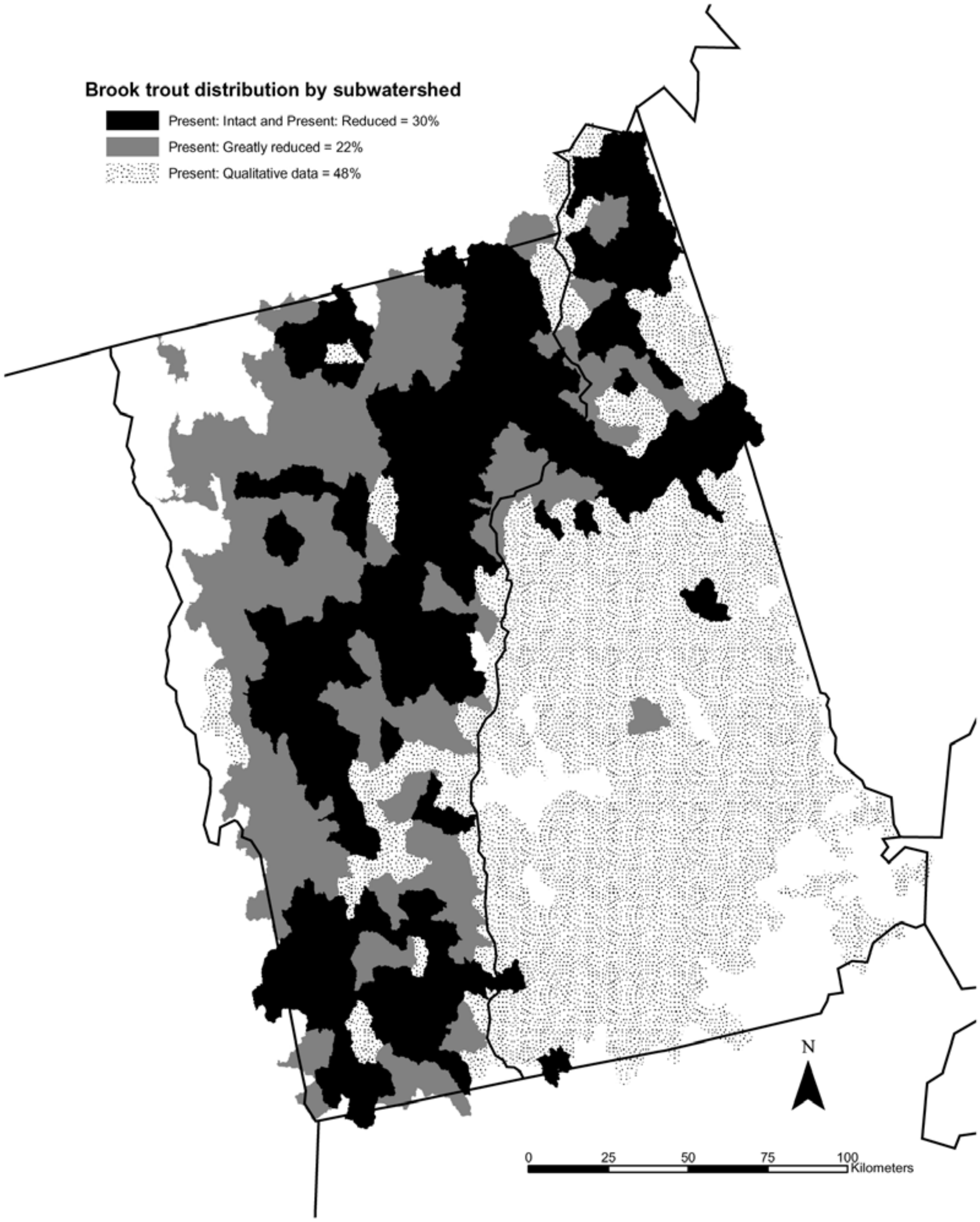
Appendix 2 Figure A2.6. Distribution of subwatersheds in Maryland, West Virginia and Virginia where brook trout are present (40 %), extirpated (26 %) or of unknown status (Unknown: no data and Absent: Unknown history) (34 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



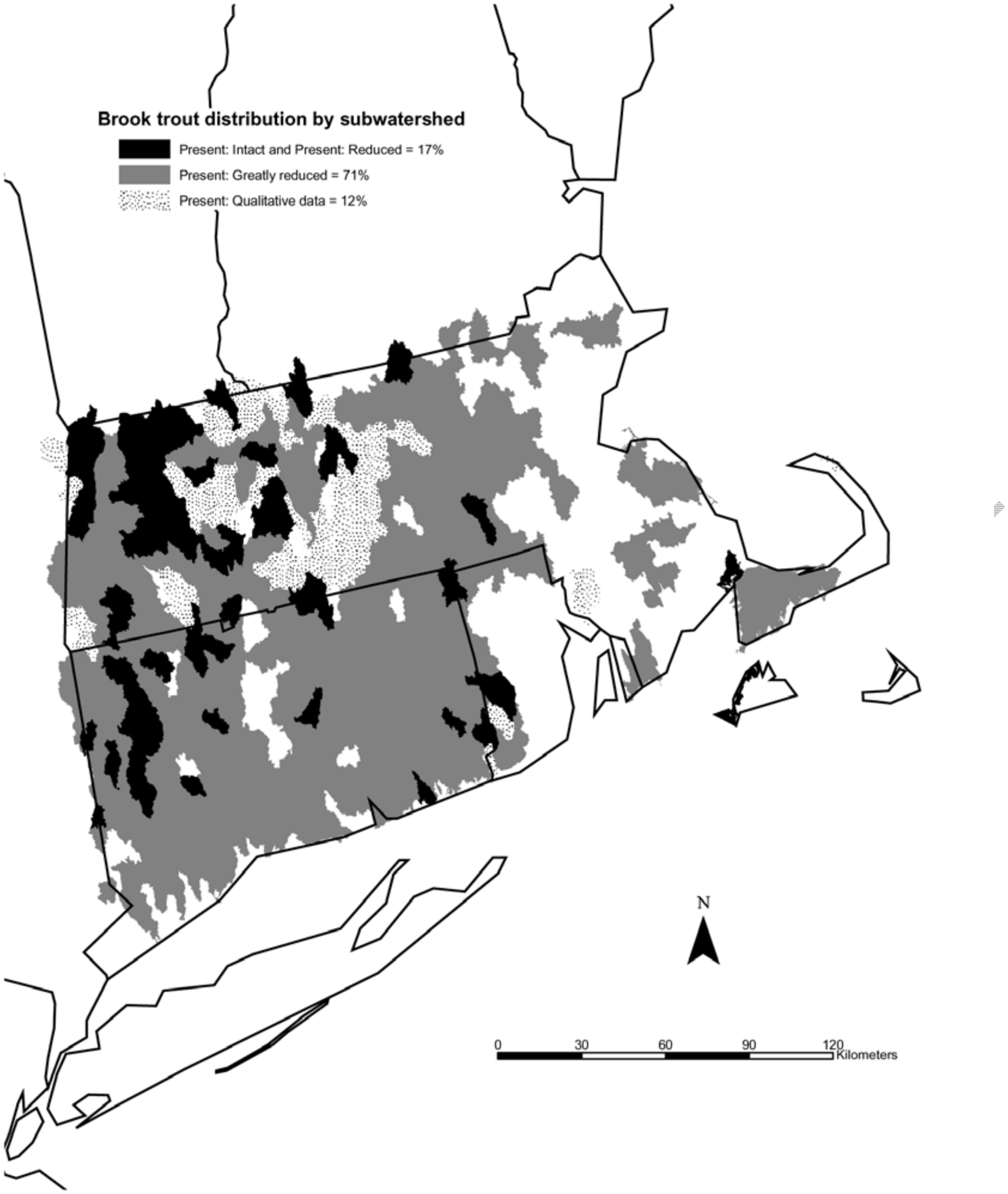
Appendix 2 Figure A2.7. Distribution of subwatersheds in North Carolina, South Carolina, Tennessee and Georgia where brook trout are present (42 %), extirpated (41 %) or of unknown status (Unknown: no data and Absent: Unknown history) (17 %). Subwatersheds classified as never occurred are not included in the percentage calculations. Additional queries can be run at: http://seris.info/ArcIMS/BT



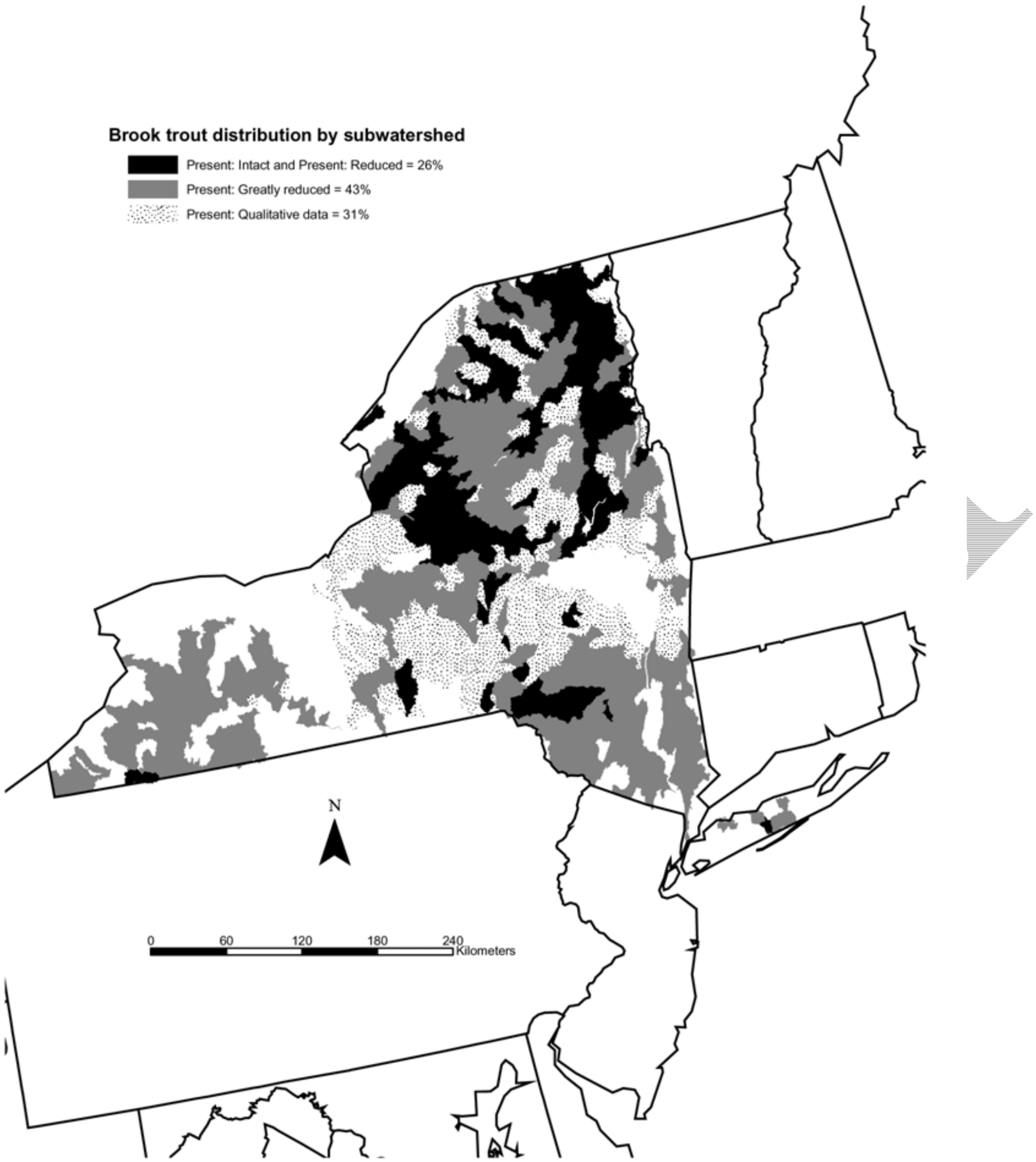
Appendix 2 Figure A2.8. Subwatersheds containing brook trout in Maine. Subwatersheds with Present: Intact and Present: Reduced (23 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (9 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (68 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT.



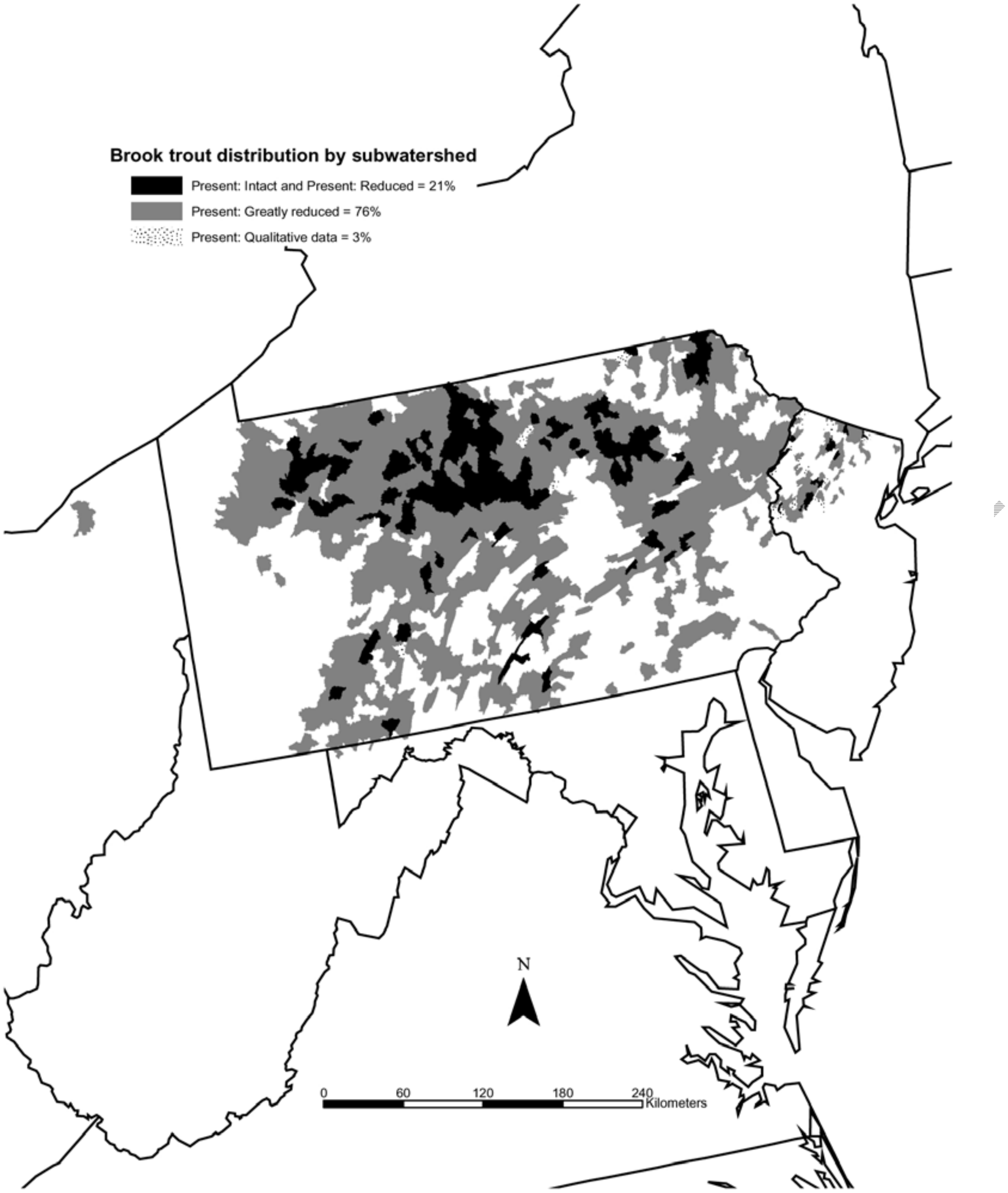
Appendix 2 Figure A2.9. Subwatersheds containing brook trout in New Hampshire and Vermont. Subwatersheds with Present: Intact and Present: Reduced (30 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (22 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (48 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT.



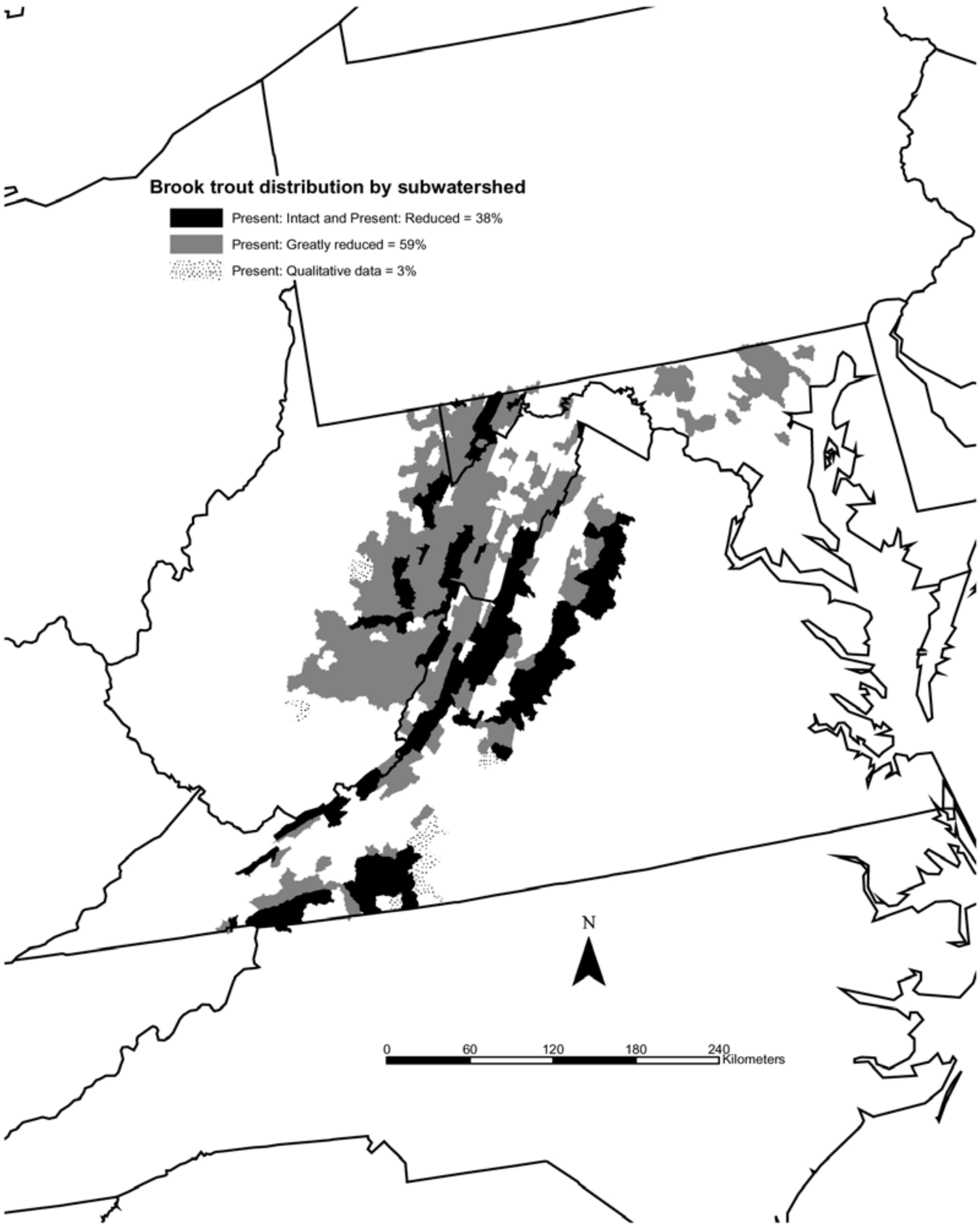
Appendix 2 Figure A2.10. Subwatersheds containing brook trout in Massachusetts, Connecticut, and Rhode Island. Subwatersheds with Present: Intact and Present: Reduced (17 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (71 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (12 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT.



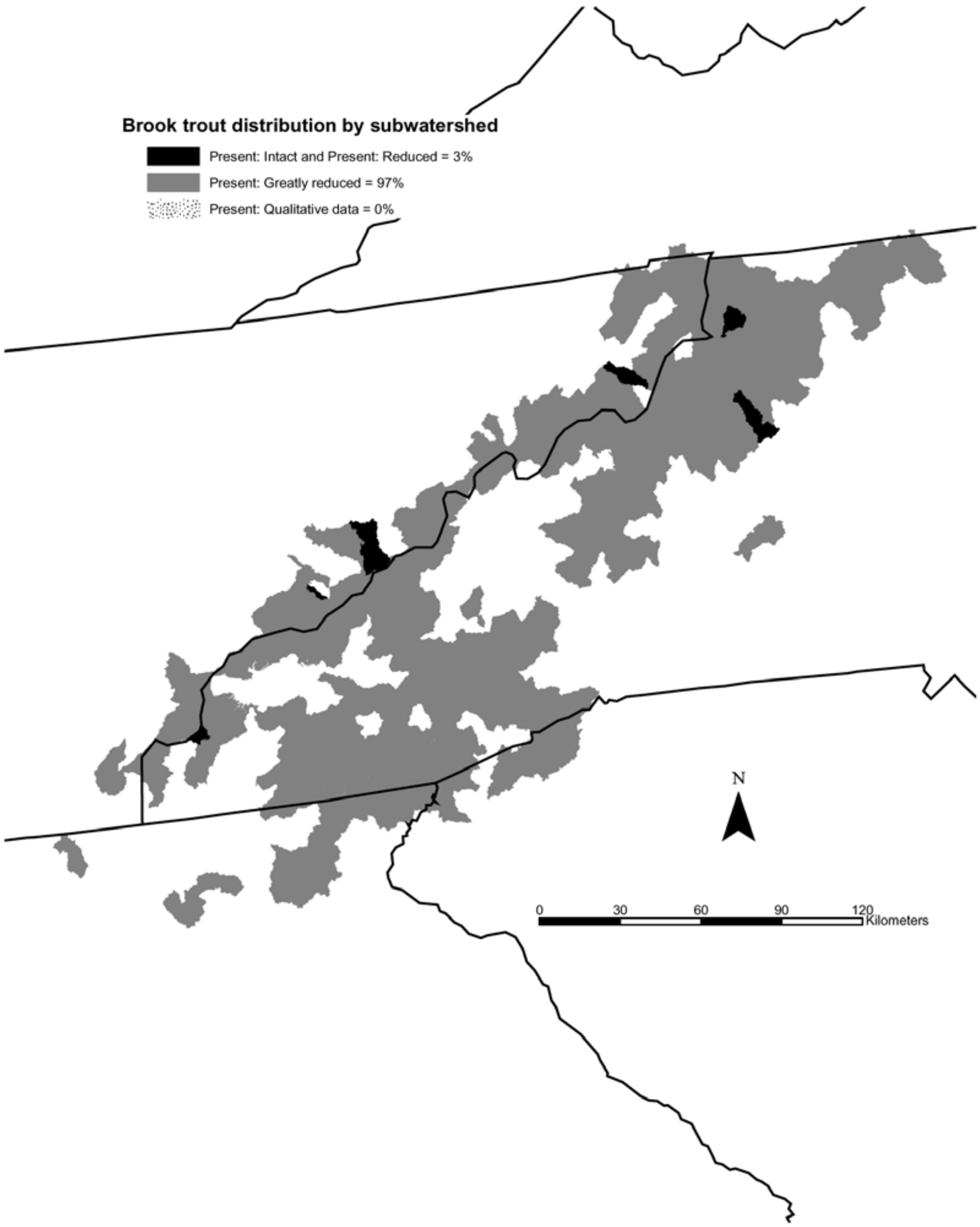
Appendix 2 Figure A2.11. Subwatersheds containing brook trout in New York. Subwatersheds with Present: Intact and Present: Reduced (26 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (43 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (31 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT



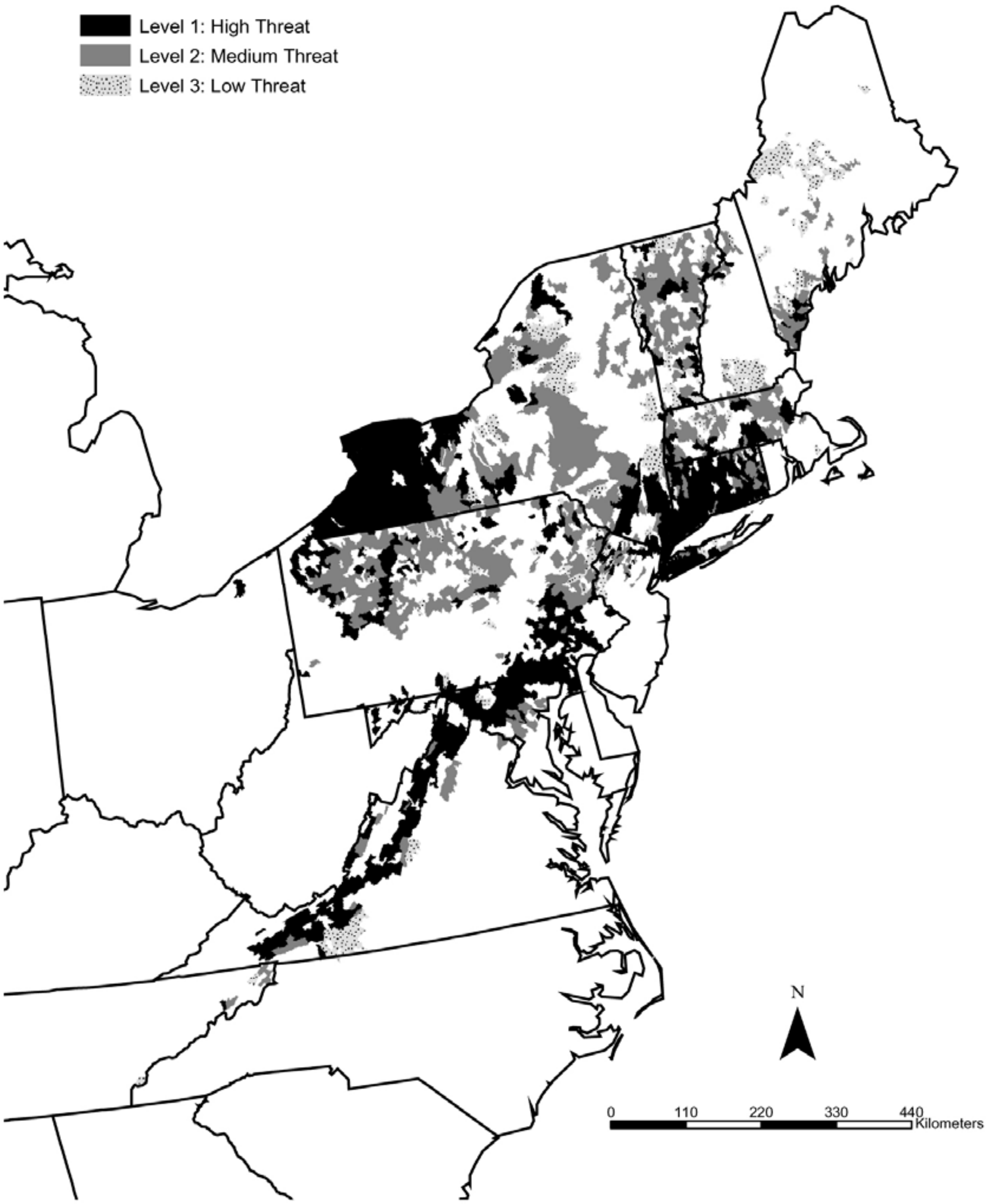
Appendix 2 Figure A2.12. Subwatersheds containing brook trout in Pennsylvania and New Jersey. Subwatersheds with Present: Intact and Present: Reduced (21 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (76 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (3 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT.



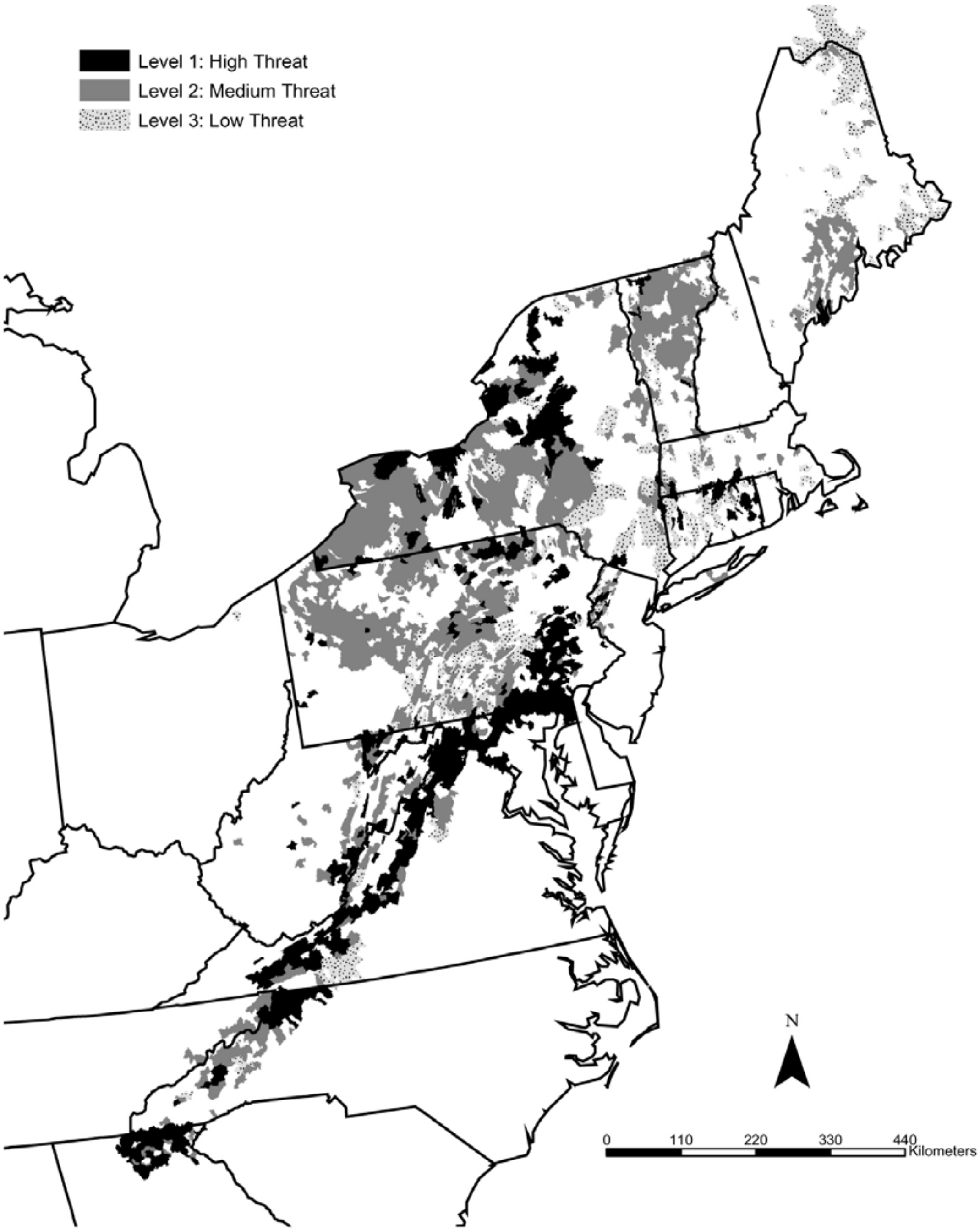
Appendix 2 Figure A2.13. Subwatersheds containing brook trout in West Virginia, Maryland and Virginia. Subwatersheds with Present: Intact and Present: Reduced (38 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (59 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (3 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT



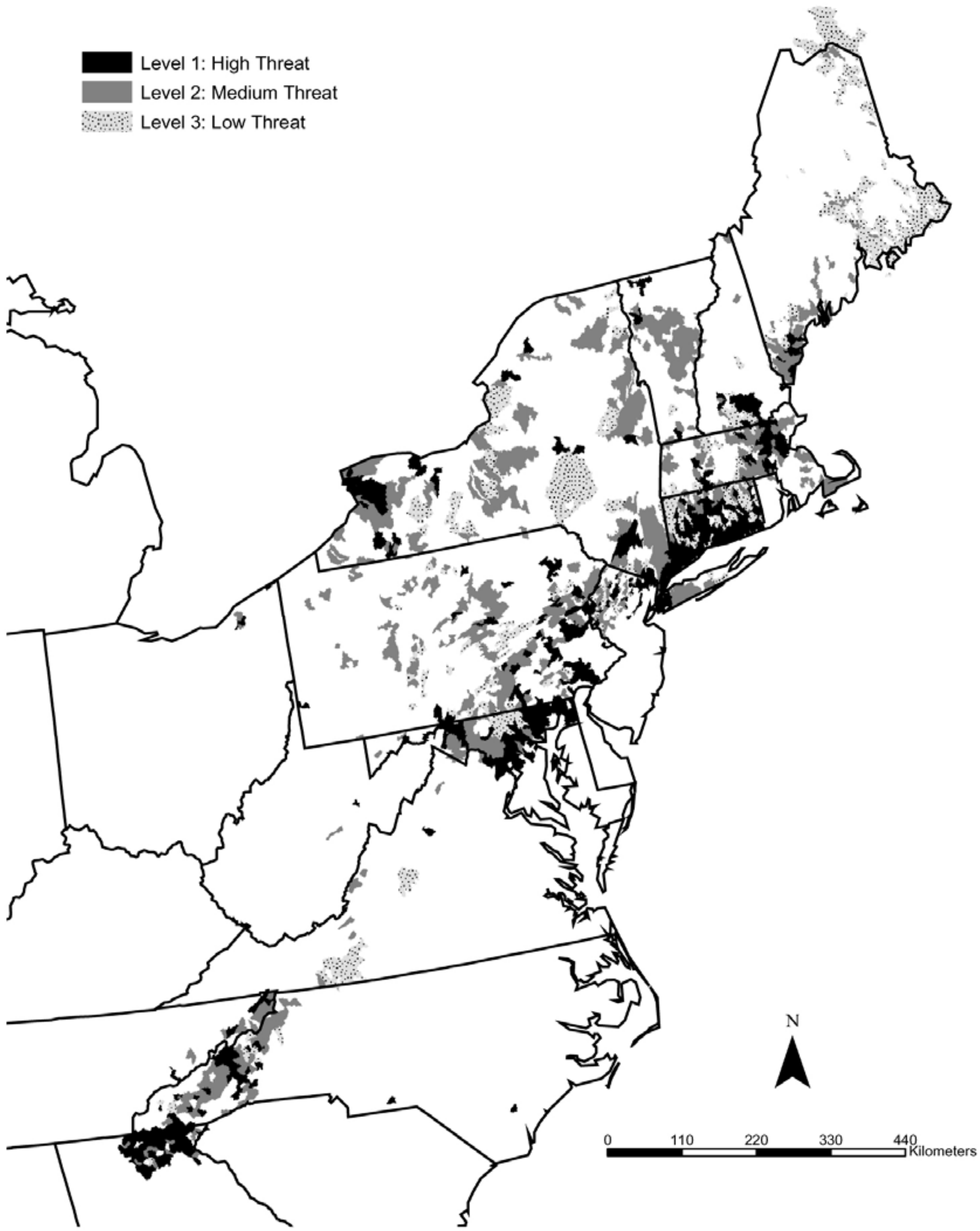
Appendix 2 Figure A2.14. Subwatersheds containing brook trout in North Carolina, South Carolina, Tennessee and Georgia. Subwatersheds with Present: Intact and Present: Reduced (3 %) have retained at least 50 % the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Greatly reduced (97 %) classifications have lost greater than 50% of the habitat maintaining reproducing populations of brook trout. Subwatersheds with a Present: Qualitative data (0 %) classifications have reproducing brook trout but the status in the subwatershed could not be determined without additional data collection. Only subwatersheds with reproducing brook trout included in the percentage calculations. See table 1 and appendix A1 for complete description of classification categories. Additional queries can be run at: http://seris.info/ArcIMS/BT



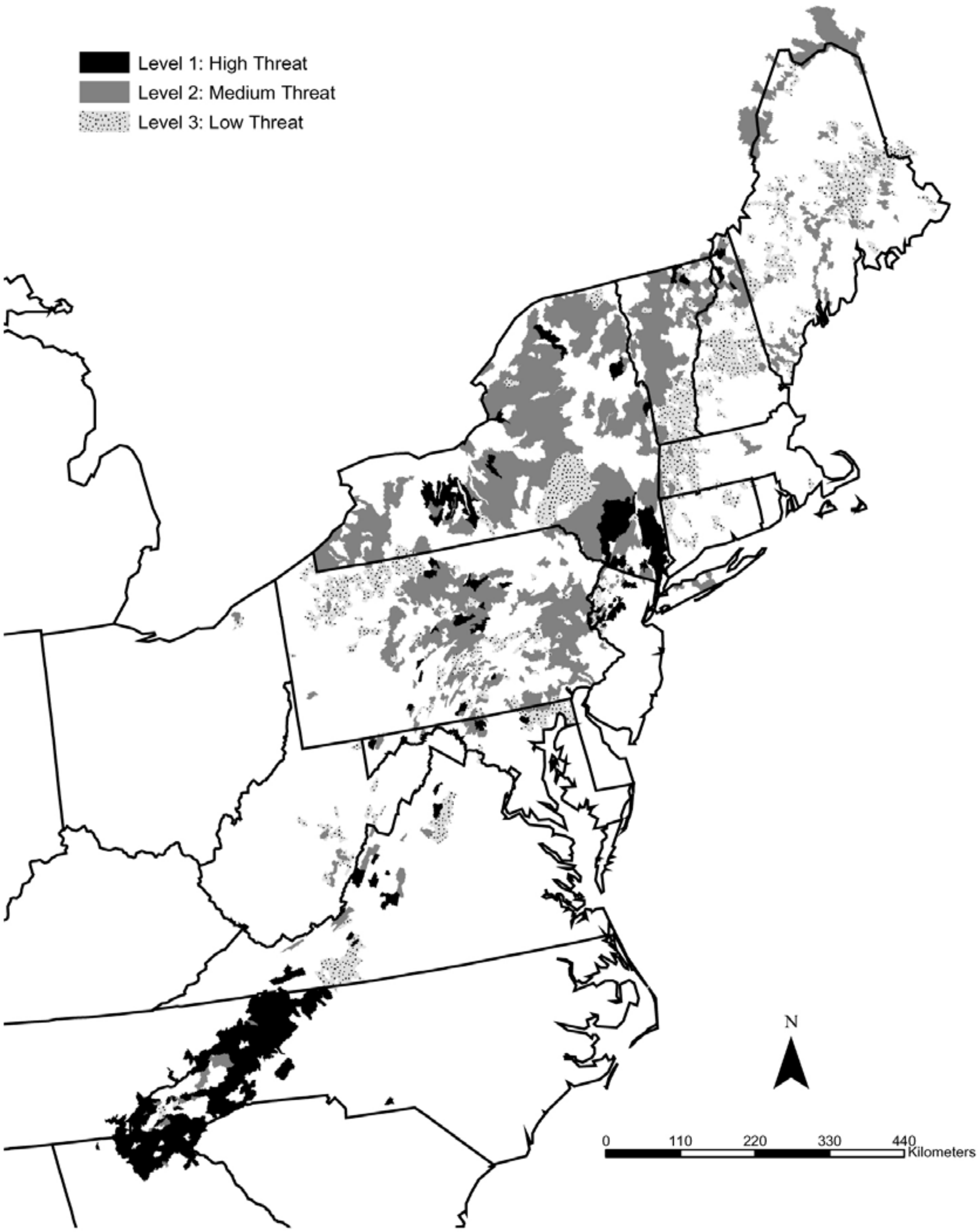
Appendix 3 Figure A3.1. Identified high water temperature (ranked as number 1 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (19.6%), Level 2 medium threat = reduction of life cycle component within subwatershed (14.9%) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (4.7%). Additional queries can be run at: http://seris.info/ArcIMS/BT.



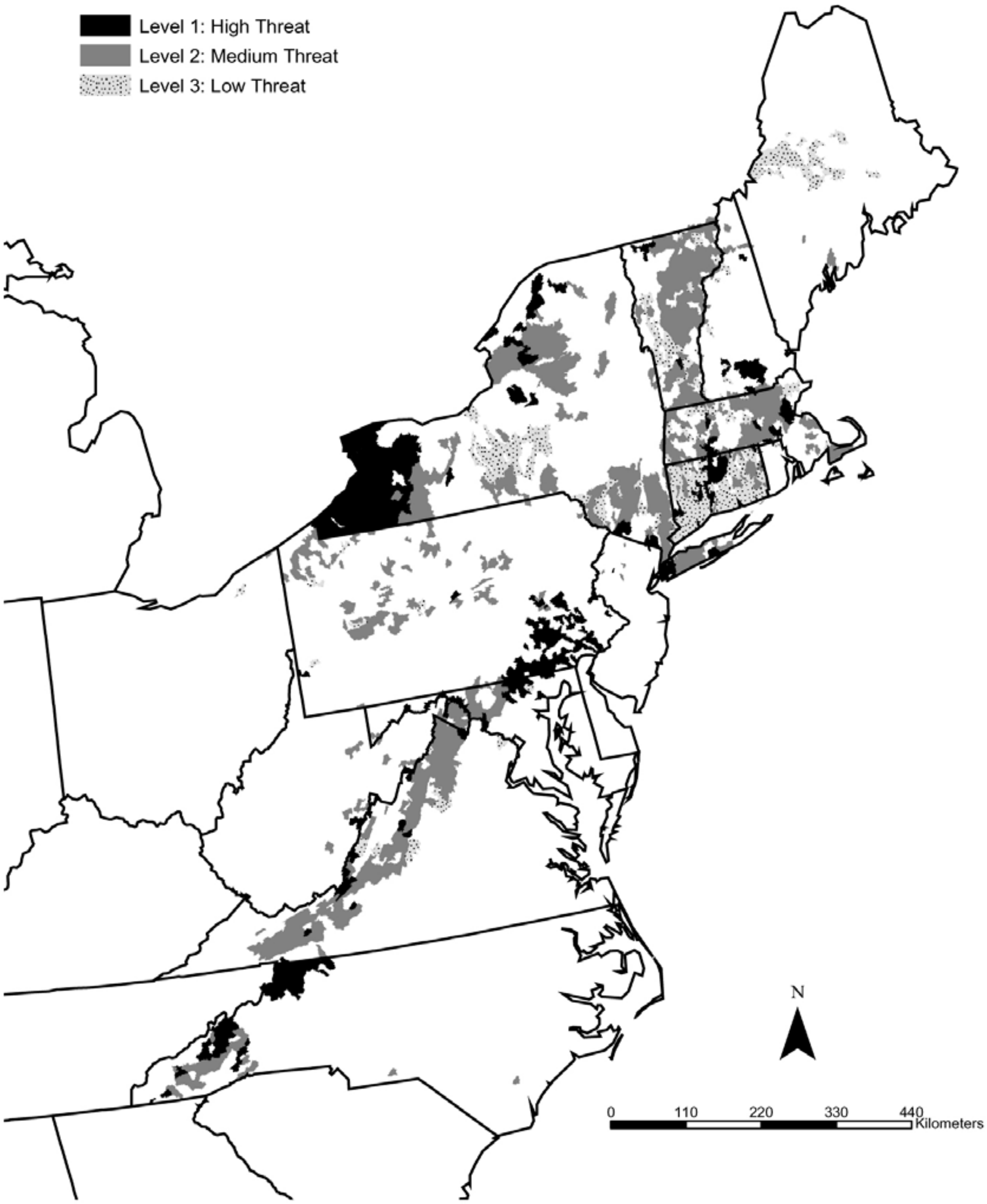
Appendix 3 Figure A3.2. Identified agriculture (ranked as number 2 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (15.3 %), Level 2 medium threat = reduction of life cycle component within subwatershed (20.4 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (7.7 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



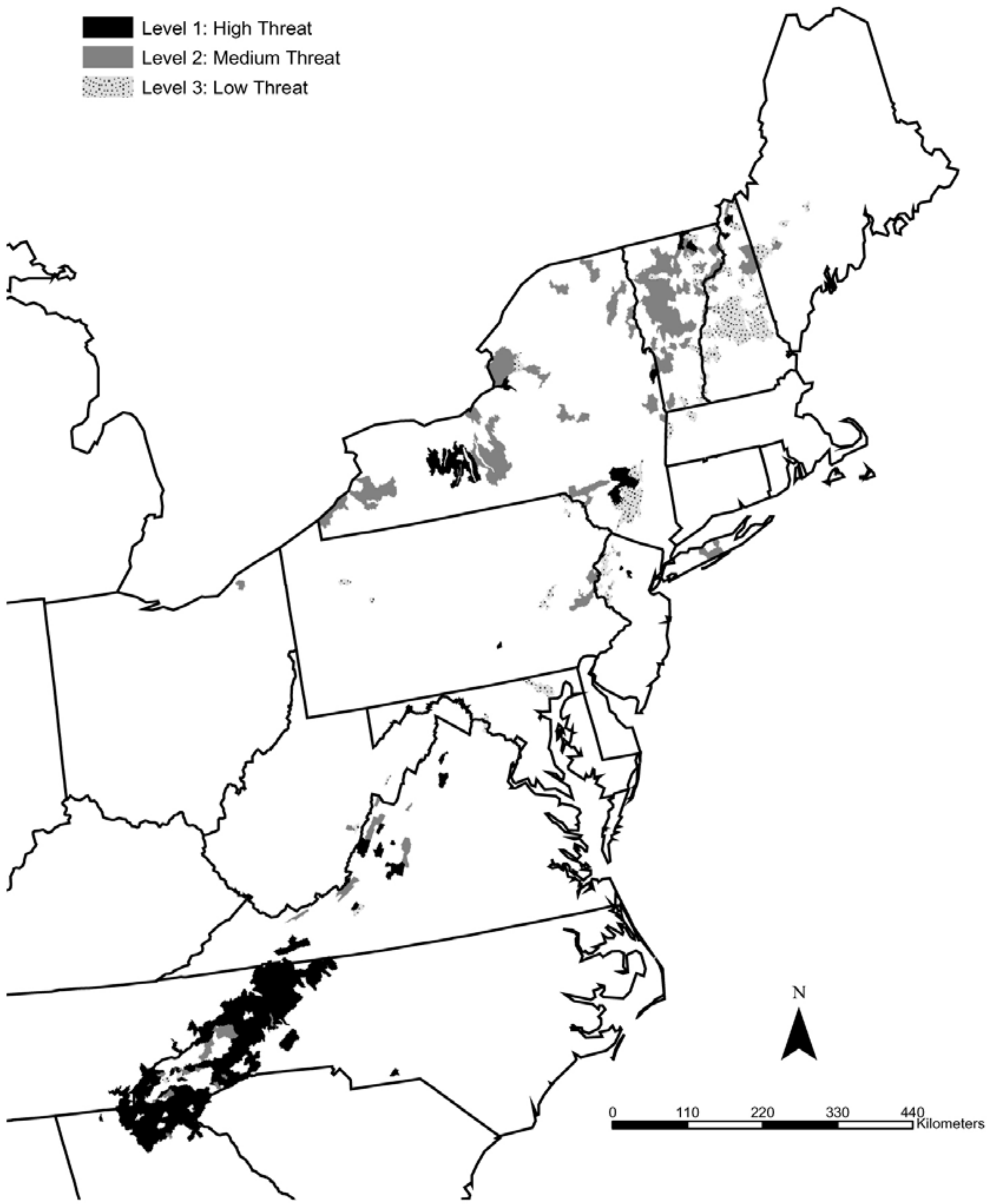
Appendix 3 Figure A3.3. Identified urbanization (ranked as number 3 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (9.7 %), Level 2 medium threat = reduction of life cycle component within subwatershed (15.3 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (7.8 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



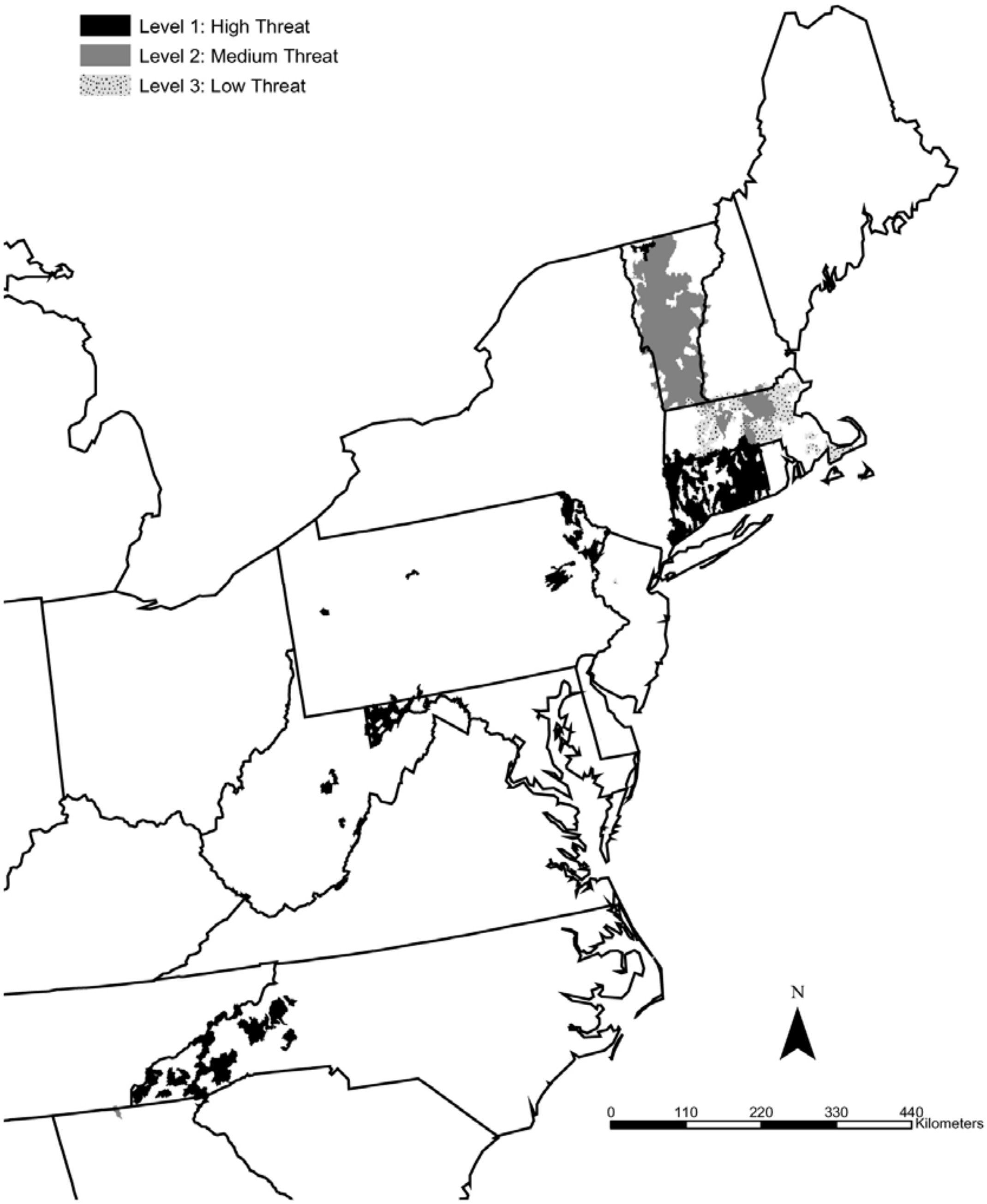
Appendix 3 Figure A3.4. Identified exotic fish (ranked as number 4 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (9.3 %), Level 2 medium threat = reduction of life cycle component within subwatershed (16.5 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (11.8%). Additional queries can be run at: http://seris.info/ArcIMS/BT.



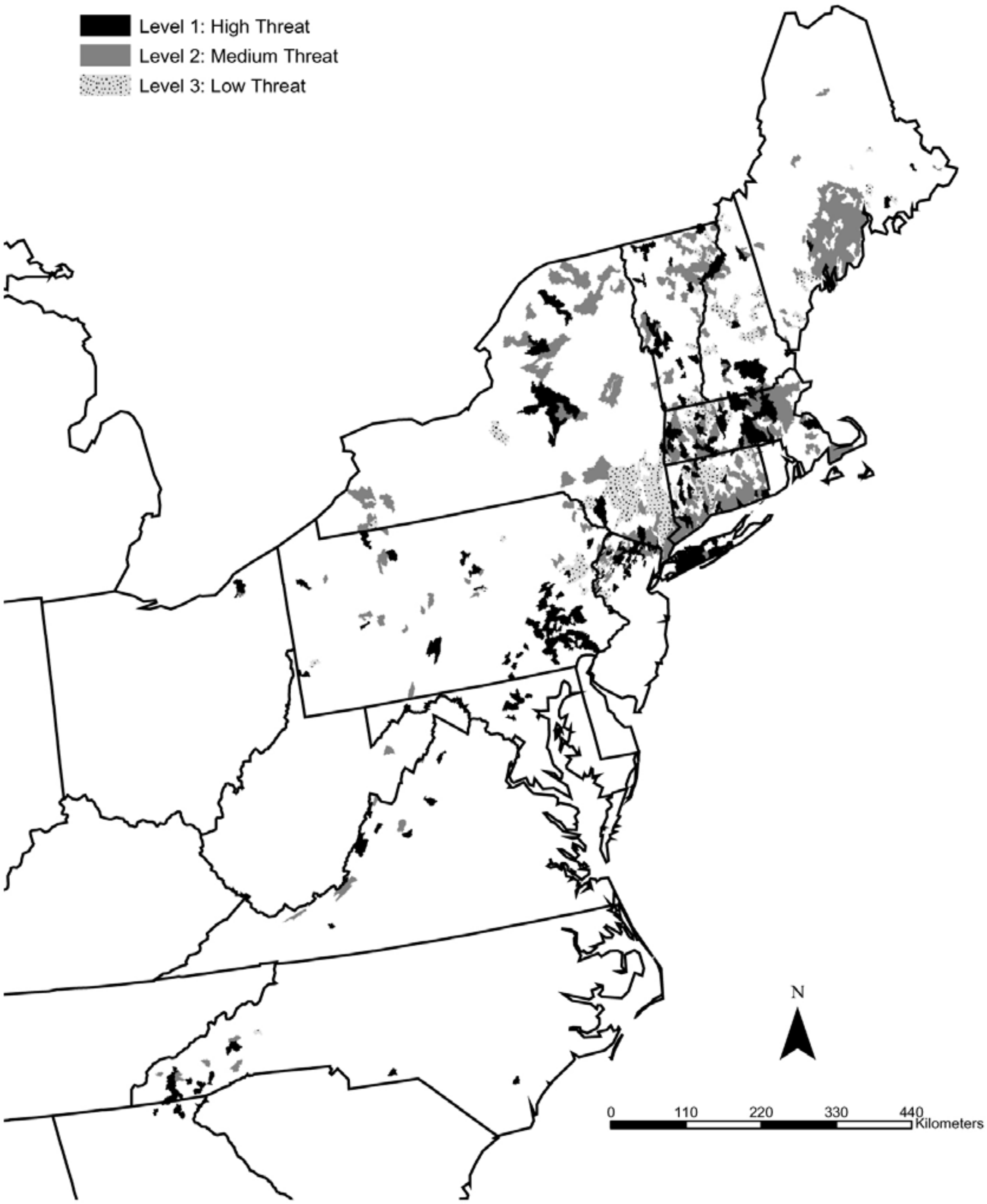
Appendix 3 Figure A3.5. Identified riparian (ranked as number 5 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (7.1 %), Level 2 medium threat = reduction of life cycle component within subwatershed (15.1 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (6.4 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



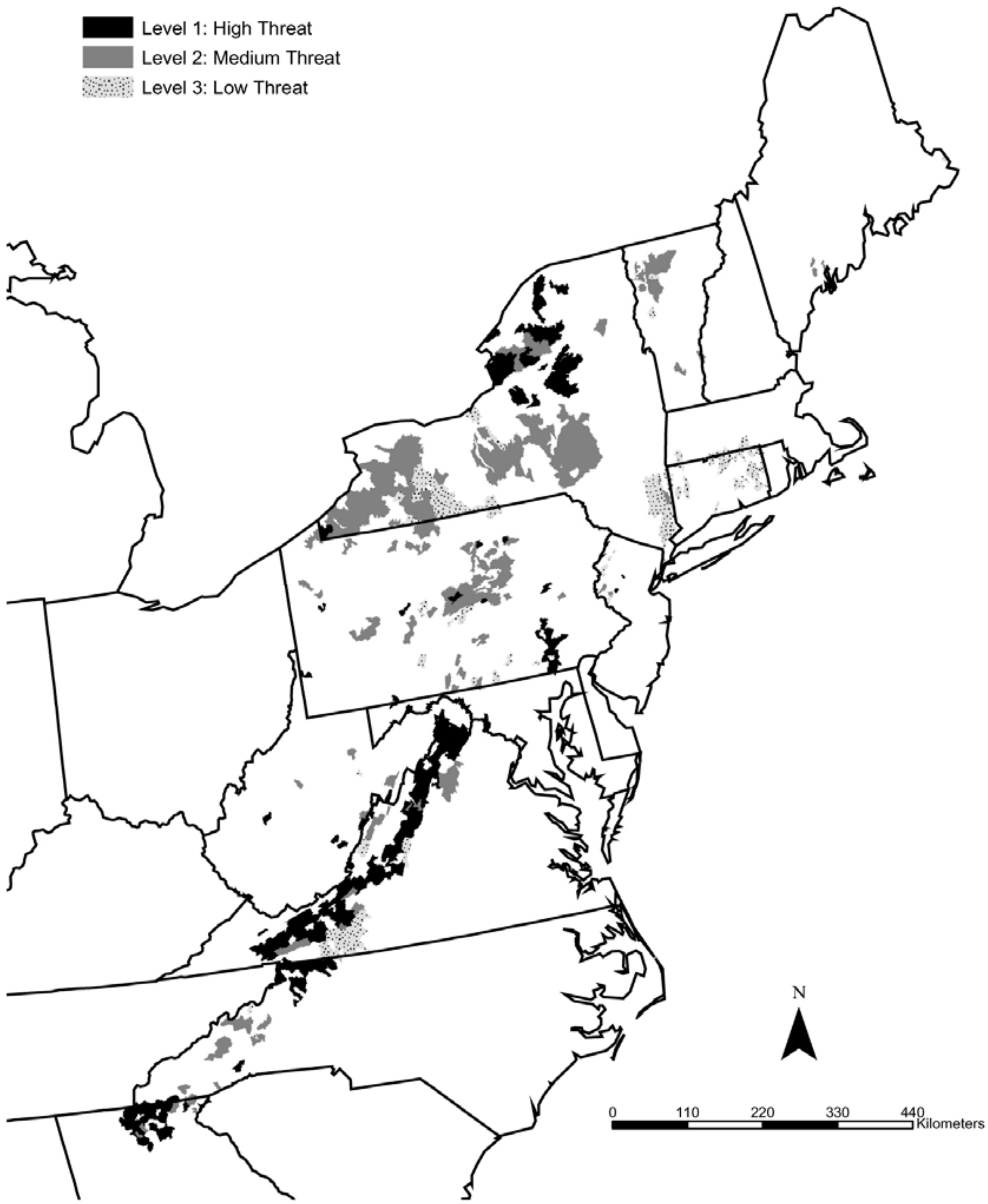
Appendix 3 Figure A3.1. Identified rainbow trout (ranked as number 6 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (6.8 %), Level 2 medium threat = reduction of life cycle component within subwatershed (4.0 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (3.0%). Additional queries can be run at: http://seris.info/ArcIMS/BT.



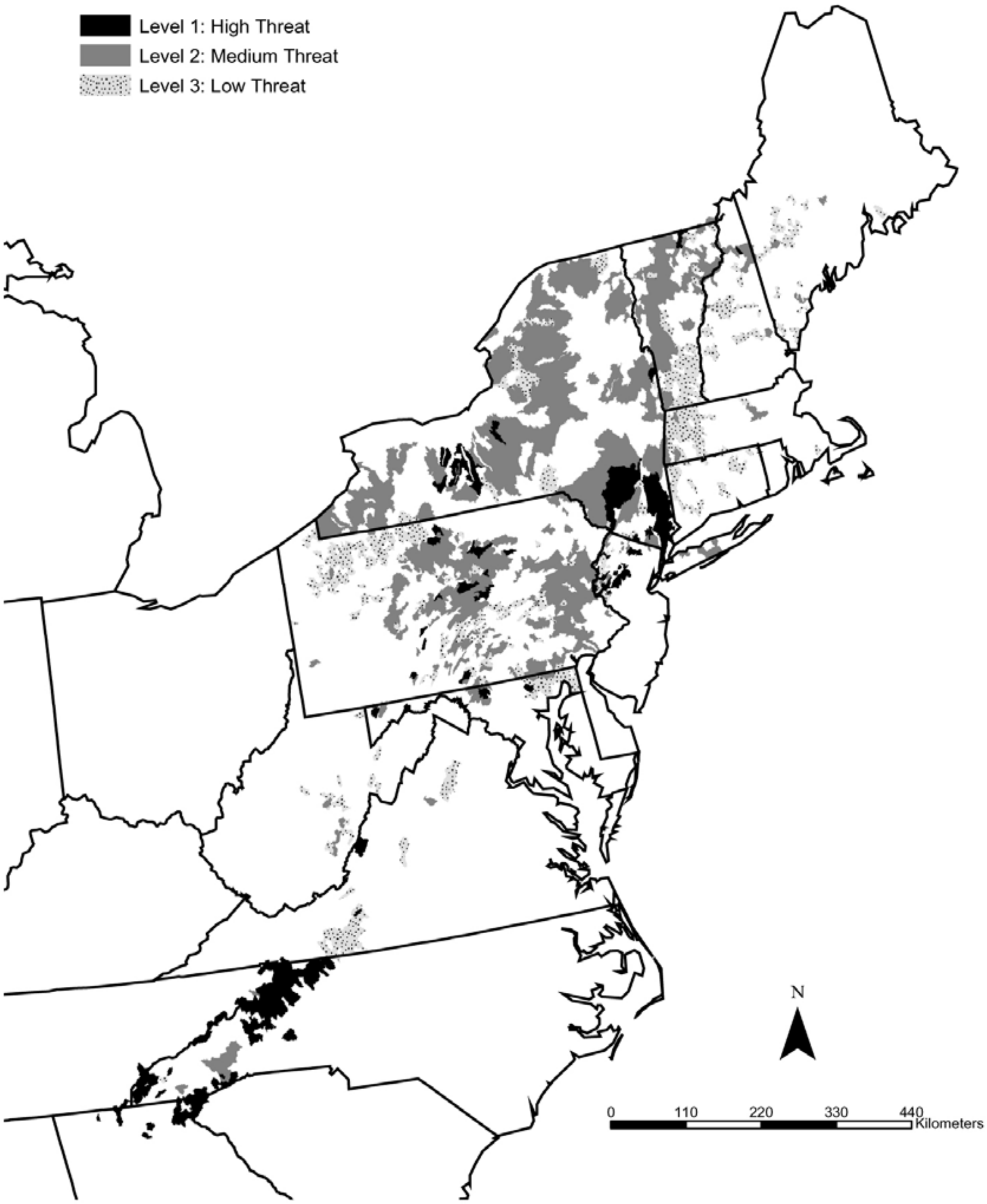
Appendix 3 Figure A3.7. Identified historic forestry (ranked as number 7 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (7.6 %), Level 2 medium threat = reduction of life cycle component within subwatershed (6.1 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (2.1%). Additional queries can be run at: http://seris.info/ArcIMS/BT.



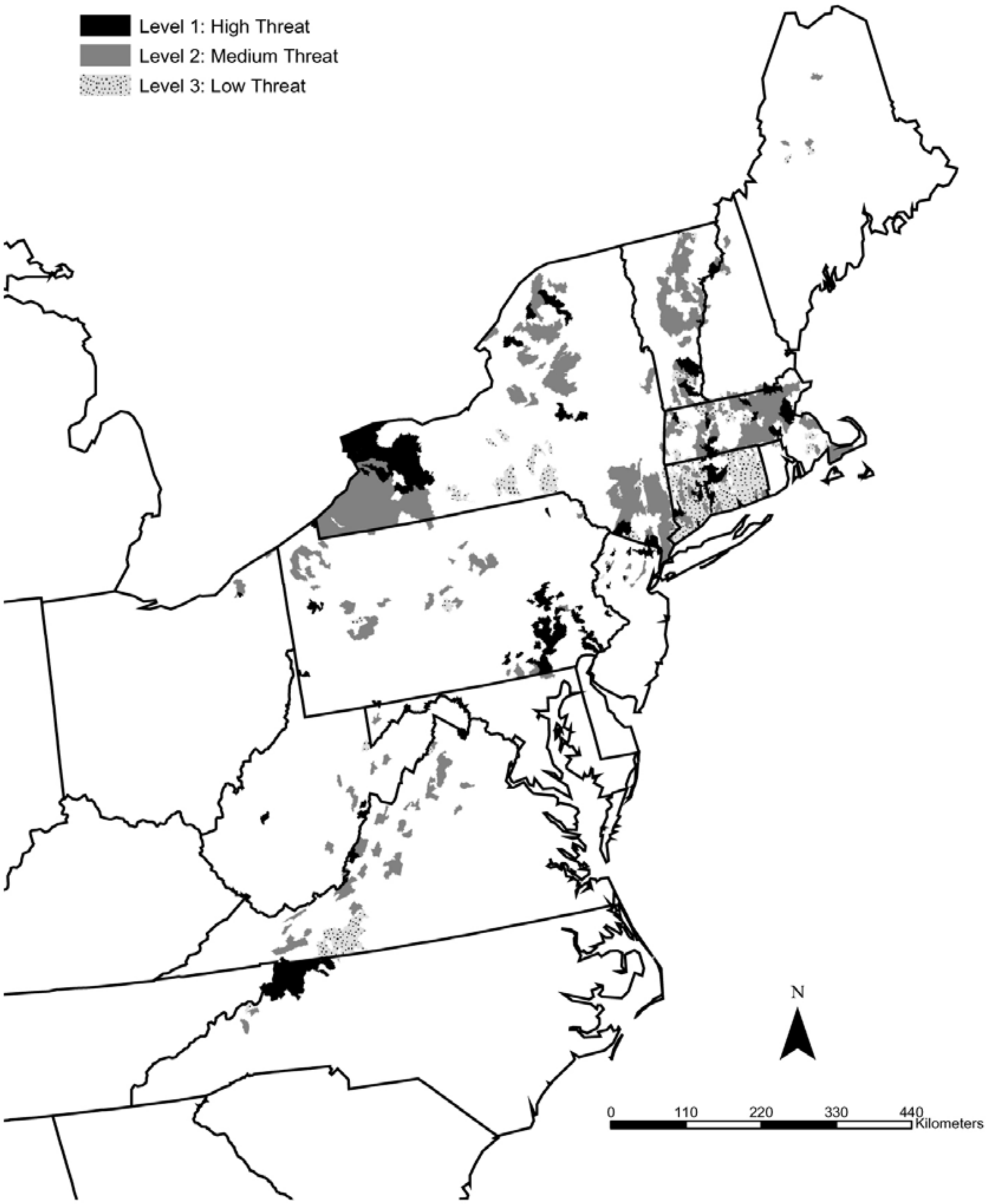
Appendix 3 Figure A3.8. Identified dam (ranked as number 8 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (6.7 %), Level 2 medium threat = reduction of life cycle component within subwatershed (8.7 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (3.3 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



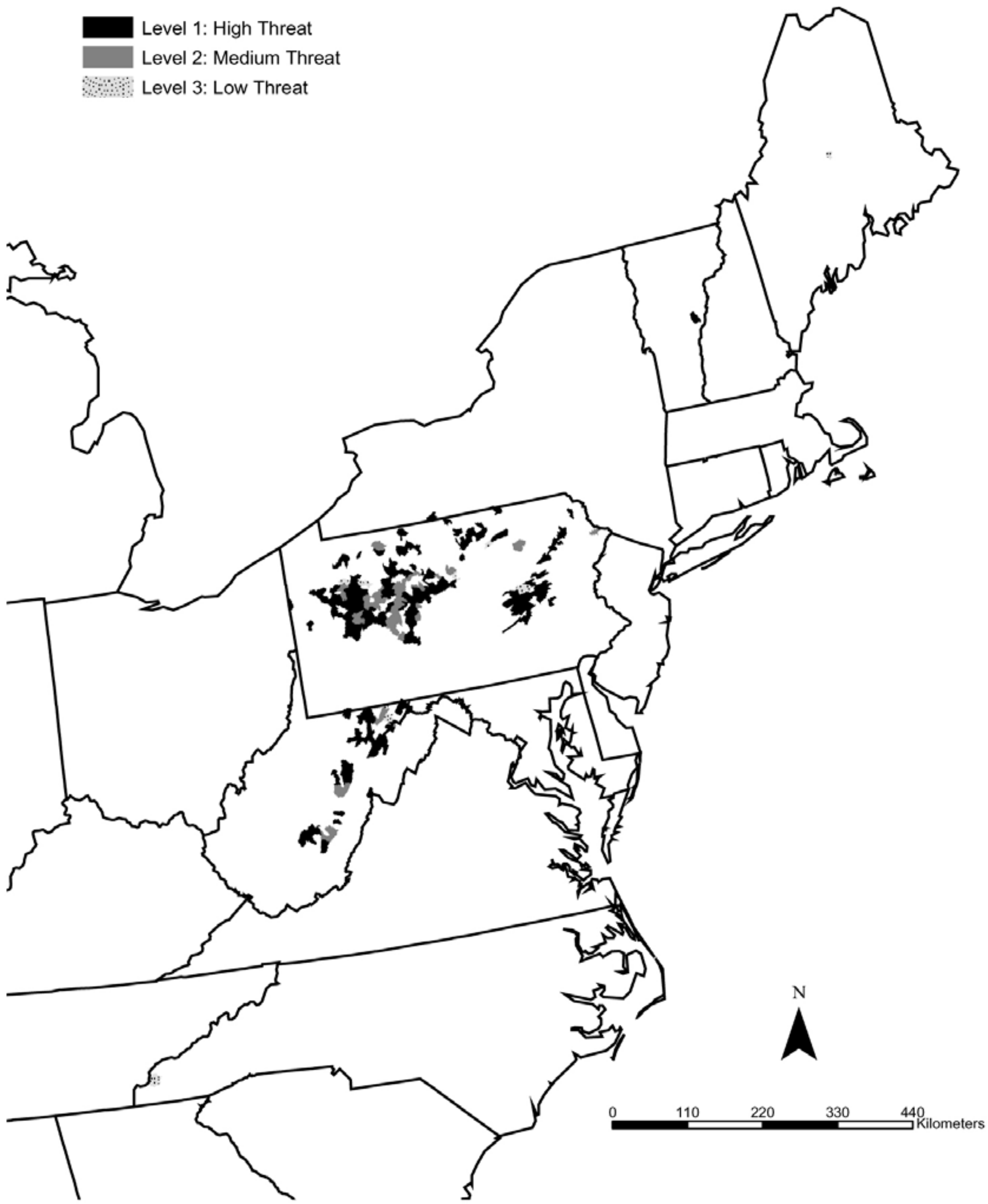
Appendix 3 Figure A3.9. Identified grazing (ranked as number 9 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (6.3 %), Level 2 medium threat = reduction of life cycle component within subwatershed (5.7 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (2.3 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



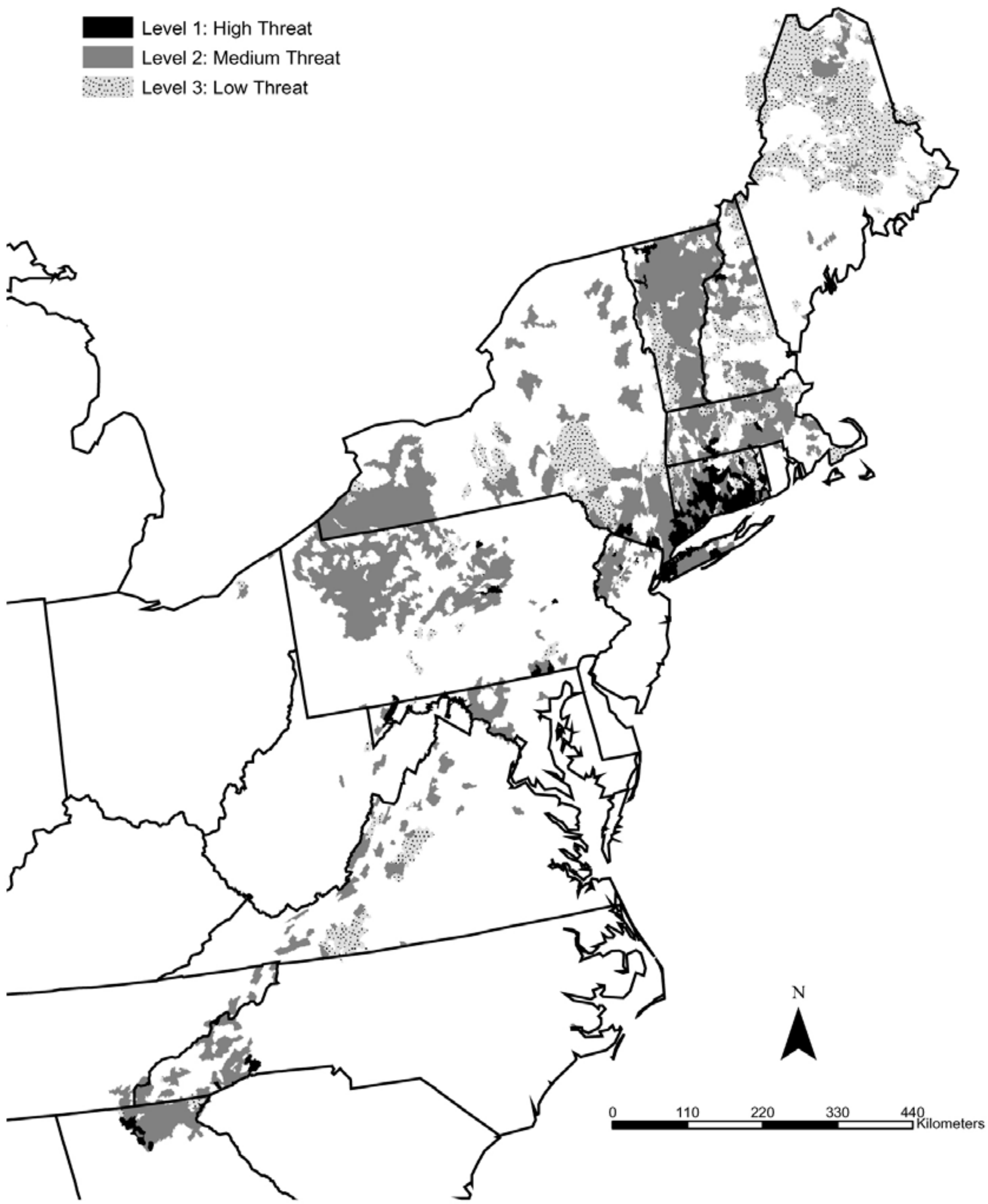
Appendix 3 Figure A3.10. Identified brown trout (ranked as number 10 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (5.2 %), Level 2 medium threat = reduction of life cycle component within subwatershed (13.7 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (8.0 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



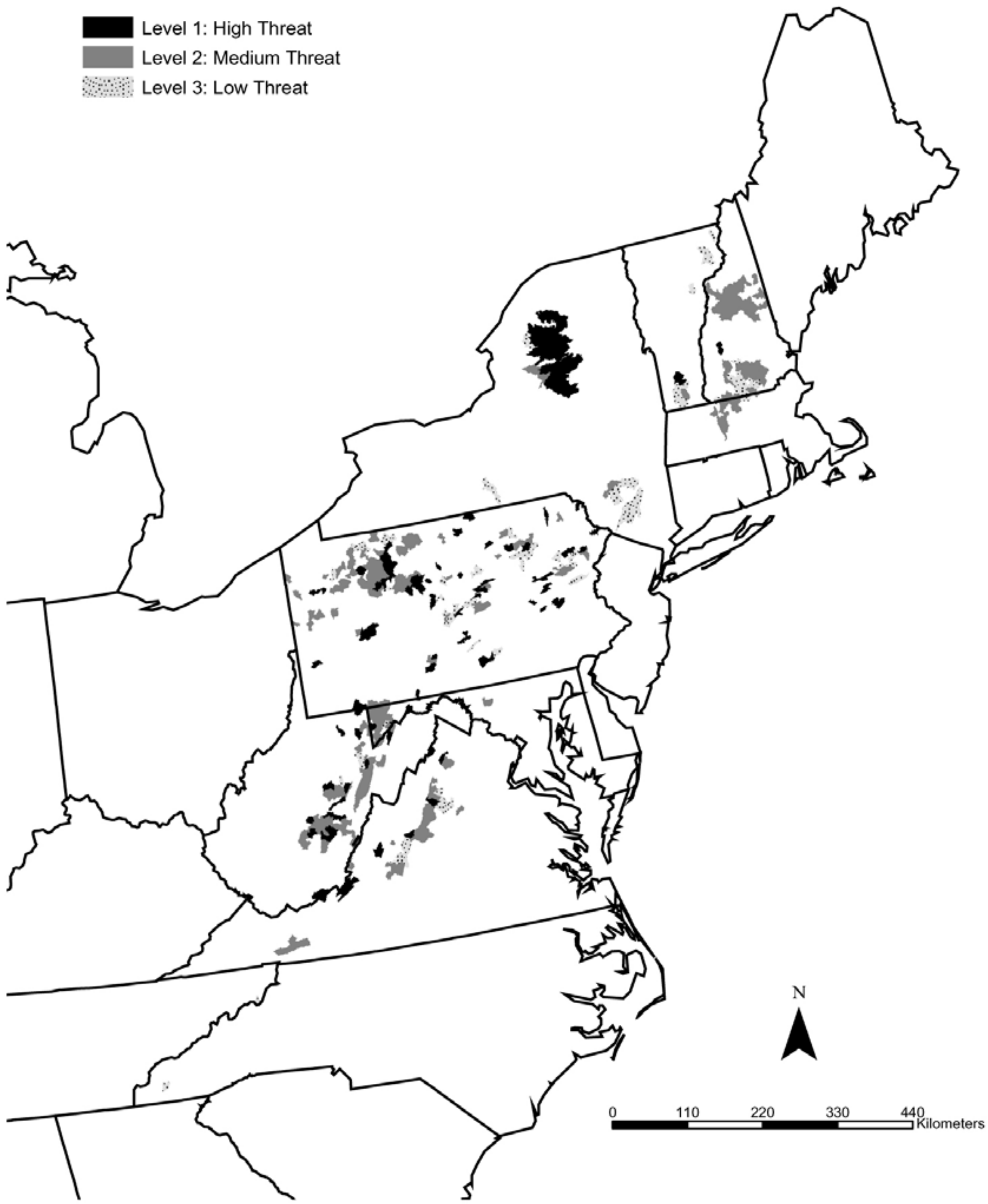
Appendix 3 Figure A3.11. Identified instream habitat (ranked as number 11 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (4.4 %), Level 2 medium threat = reduction of life cycle component within subwatershed (8.3 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (3.7 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



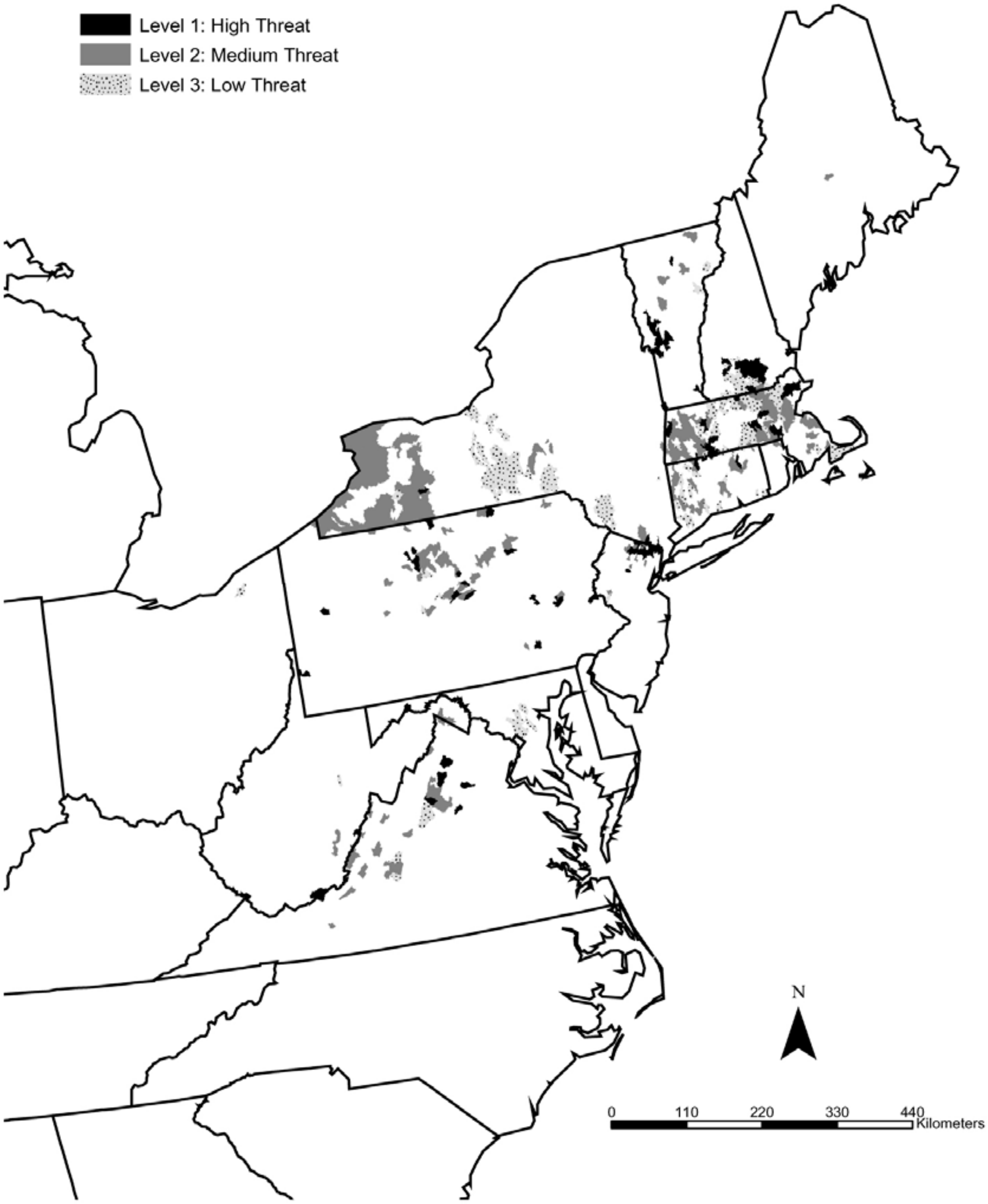
Appendix 3 Figure A3.12. Identified acid mine drainage (ranked as number 12 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (4.0 %), Level 2 medium threat = reduction of life cycle component within subwatershed (1.0 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (0.3 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



Appendix 3 Figure A3.13. Identified road sediment (ranked as number 13 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (3.5 %), Level 2 medium threat = reduction of life cycle component within subwatershed (23.5 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (12.9 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



Appendix 3 Figure A3.14. Identified acid rain (ranked as number 14 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (2.5 %), Level 2 medium threat = reduction of life cycle component within subwatershed (4.3 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (1.2 %). Additional queries can be run at: http://seris.info/ArcIMS/BT.



Appendix 3 Figure A3.15. Identified minimum flow (ranked as number 15 threat) threats to brook trout. Threats determined by expert opinion from 4,484 subwatersheds. Level 1 high threat = loss of life cycle component within subwatershed (2.0 %), Level 2 medium threat = reduction of life cycle component within subwatershed (4.6 %) and Level 3 low threat = general concern, no documented loss or reduction of life cycle components (2.3%). Additional queries can be run at: http://seris.info/ArcIMS/BT.

Appendix 3 Table 1. Streams State summary of Level 1 high threats to brook trout.

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical																		
Minimum flow	0	0	12	17		2	2	28	17	0	2	10	0	0		0	0	**90**
Surface water withdrawals	0	0	1	1		0	17	1	3	0	0	1	0	0		0	0	**24**
Ground water withdrawals	0	0	0	0		3	0	5	4	0	0	0	0	0		0	0	**12**
Floods	0	1	0	0		1	0	0	5	0	0	0	3	0		0	0	**10**
Debris flows	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Dams (inundation)	4	7	27	44		31	18	60	66	2	0	11	7	20		0	5	**302**
Stream fragmentation (roads)	0	0	1	15		14	0	14	5	1	0	3	7	0		0	2	**62**
In stream/lake habitat	0	2	11	19		43	18	20	51	1	0	2	1	31		0	0	**199**
Riparian habitat	0	1	5	14		89	28	1	74	0	14	15	10	67		0	0	**318**
Historic Sediment- roads	0	0	0			0	0	0	0	0	0	0	0	0		0	0	**0**
Sediment – roads	0	1	5	4		15	84	7	9	0	6	0	4	7		1	13	**156**
Non-road sediment																		
Historic agriculture	0	0	4	0		30	0	0	6	0	0	1	40	0		0	7	**88**
Agriculture	0	0	6	0		67	38	18	160	0	59	151	84	40		1	65	**689**
Urbanization	8	0	8	28		42	100	54	69	2	7	4	69	42		5	0	**438**
Historic forestry	0	0	4	0		24	138	0	0	0	9	17	28	82		0	2	**304**
Forestry	0	0	0	0		3	0	2	6	0	18	1	0	16		2	0	**48**
Recreation	0	2	0	0		2	0	6	1	0	1	0	0	2		0	2	**16**
Historic grazing	0	0	0	0		0	0	0	38	0	0	1	0	0		0	0	**39**
Grazing	0	0	0	0		31	0	4	22	0	7	149	2	27		0	44	**286**
Mining	0	0	1	1		0	0	2	39	0	22	1	1	10		0	0	**77**
Chemical																		
Low pH -Acid rain	0	1	2	0		20	0	0	55	0	18	13	1	0		3	0	**113**
Low pH -Acid mine drainage	0	0	1	0		0	0	0	136	0	36	0	7	0		0	0	**180**
Dissolved oxygen	0	0	0	0		0	0	0	5	0	0	0	1	0		0	0	**6**
Water temperature – high	8	3	33	30		157	137	48	191	4	6	160	93	0		13	0	**883**
Water temperature low	0	1	0	0		0	0	1	0	0	0	0	1	0		0	0	**3**
Eutrophication	1	1	4	0		12	18	17	27	0	0	0	2	0		0	0	**82**
Gas super saturation	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Turbidity	0	0	4	0		0	0	0	1	0	0	1	0	0		0	0	**6**
Heavy metals	0	0	0	0		2	0	0	16	0	0	0	0	0		0	0	**18**
Pesticides	0	0	0	0		0	0	0	0	0	0	23	2	1		0	0	**26**

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Historic pesticides	0	0	0	0		3	0	0	0	0	0	0	0	0		0	0	**3**
Biological																		
All exotics	0	5	4	0		44	0	47	22	0	0	25	4	143		38	86	**418**
<u>Exotics coldwater</u>																		
Rainbow trout	0	2	4	0		12	0	4	1	0	0	23	0	138		37	86	**307**
Brown trout	0	2	3	0		34	0	47	21	0	0	5	4	85		8	26	**235**
Lake trout	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Landlocked salmon	0	1	0	0		0	0	0	0	0	0	0	0	0		0	0	**1**
Other_______	0	1	0	0		0	0	0	0	0	0	0	0	0		0	0	**1**
<u>Exotics cool/warm water</u>																		
Smallmouth bass	0	0	0	0		5	0	0	0	0	0	0	0	0		0	0	**5**
Largemouth bass	0	1	0	0		1	0	0	0	0	0	0	0	0		0	0	**2**
Walleye	0	0	0	0		3	0	0	0	0	0	0	0	0		0	0	**3**
Northern pike	0	0	0	0		4	0	0	0	0	0	0	0	0		0	0	**4**
Other_______	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Aquatic weeds	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Over fishing – legal	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Poaching	0	0	0	0		0	0	0	0	0	0	1	0	0		0	0	**1**
Forest pests and disease	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Diseases	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Beavers	0	0	0	1		56	0	5	1	0	0	0	1	0		0	0	**64**
Bird predation	0	0	0	0		4	0	0	0	0	0	0	0	0		0	0	**4**
Historic over fishing	0	0	0	0		0	1	0	0	0	0	0	0	0		0	0	**1**
Historic Mining	0	0	0	0		0	0	0	0	0	0	0	0	0		0	1	**1**
Total	**21**	**32**	**140**	**174**		**754**	**599**	**391**	**1051**	**10**	**205**	**618**	**372**	**711**		**108**	**339**	**5525**

Appendix 3 Table 2. Streams 1 +2

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical																		
Minimum flow	0	0	12	17		2	2	28	17	0	2	10	0	0		0	0	**90**
Surface water withdrawals	0	0	1	1		0	17	1	3	0	0	1	0	0		0	0	**24**
Ground water withdrawals	0	0	0	0		3	0	5	4	0	0	0	0	0		0	0	**12**
Floods	0	1	0	0		1	0	0	5	0	0	0	3	0		0	0	**10**
Debris flows	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Dams (inundation)	4	7	27	44		31	18	60	66	2	0	11	7	20		0	5	**302**
Stream fragmentation (roads)	0	0	1	15		14	0	14	5	1	0	3	7	0		0	2	**62**
In stream/lake habitat	0	2	11	19		43	18	20	51	1	0	2	1	31		0	0	**199**
Riparian habitat	0	1	5	14		89	28	1	74	0	14	15	10	67		0	0	**318**
Historic Sediment- roads	0	0	0			0	0	0	0	0	0	0	0	0		0	0	**0**
Sediment – roads	0	1	5	4		15	84	7	9	0	6	0	4	7		1	13	**156**
Non-road sediment																		
Historic agriculture	0	0	4	0		30	0	0	6	0	0	1	40	0		0	7	**88**
Agriculture	0	0	6	0		67	38	18	160	0	59	151	84	40		1	65	**689**
Urbanization	8	0	8	28		42	100	54	69	2	7	4	69	42		5	0	**438**
Historic forestry	0	0	4	0		24	138	0	0	0	9	17	28	82		0	2	**304**
Forestry	0	0	0	0		3	0	2	6	0	18	1	0	16		2	0	**48**
Recreation	0	2	0	0		2	0	6	1	0	1	0	0	2		0	2	**16**
Historic grazing	0	0	0	0		0	0	0	38	0	0	1	0	0		0	0	**39**
Grazing	0	0	0	0		31	0	4	22	0	7	149	2	27		0	44	**286**
Mining	0	0	1	1		0	0	2	39	0	22	1	1	10		0	0	**77**
Chemical																		
Low pH -Acid rain	0	1	2	0		20	0	0	55	0	18	13	1	0		3	0	**113**
Low pH -Acid mine drainage	0	0	1	0		0	0	0	136	0	36	0	7	0		0	0	**180**
Dissolved oxygen	0	0	0	0		0	0	0	5	0	0	0	1	0		0	0	**6**
Water temperature – high	8	3	33	30		157	137	48	191	4	6	160	93	0		13	0	**883**
Water temperature low	0	1	0	0		0	0	1	0	0	0	0	1	0		0	0	**3**
Eutrophication	1	1	4	0		12	18	17	27	0	0	0	2	0		0	0	**82**
Gas super saturation	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Turbidity	0	0	4	0		0	0	0	1	0	0	1	0	0		0	0	**6**
Heavy metals	0	0	0	0		2	0	0	16	0	0	0	0	0		0	0	**18**
Pesticides	0	0	0	0		0	0	0	0	0	0	23	2	1		0	0	**26**
Historic pesticides	0	0	0	0		3	0	0	0	0	0	0	0	0		0	0	**3**

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Biological																		
All exotics	0	5	4	0		44	0	47	22	0	0	25	4	143		38	86	**418**
<u>Exotics coldwater</u>																		
Rainbow trout	0	2	4	0		12	0	4	1	0	0	23	0	138		37	86	**307**
Brown trout	0	2	3	0		34	0	47	21	0	0	5	4	85		8	26	**235**
Lake trout	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Landlocked salmon	0	1	0	0		0	0	0	0	0	0	0	0	0		0	0	**1**
Other_______	0	1	0	0		0	0	0	0	0	0	0	0	0		0	0	**1**
<u>Exotics cool/warm water</u>																		
Smallmouth bass	0	0	0	0		5	0	0	0	0	0	0	0	0		0	0	**5**
Largemouth bass	0	1	0	0		1	0	0	0	0	0	0	0	0		0	0	**2**
Walleye	0	0	0	0		3	0	0	0	0	0	0	0	0		0	0	**3**
Northern pike	0	0	0	0		4	0	0	0	0	0	0	0	0		0	0	**4**
Other_______	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Aquatic weeds	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Over fishing – legal	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Poaching	0	0	0	0		0	0	0	0	0	0	1	0	0		0	0	**1**
Forest pests and disease	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Diseases	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	**0**
Beavers	0	0	0	1		56	0	5	1	0	0	0	1	0		0	0	**64**
Bird predation	0	0	0	0		4	0	0	0	0	0	0	0	0		0	0	**4**
Historic over fishing	0	0	0	0		0	1	0	0	0	0	0	0	0		0	0	**1**
Historic Mining	0	0	0	0		0	0	0	0	0	0	0	0	0		0	1	**1**
Total	**21**	**32**	**140**	**174**		**754**	**599**	**391**	**1051**	**10**	**205**	**618**	**372**	**711**		**108**	**339**	**5525**

Appendix 3 Table 3. all Streams

Threats	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical																		
Minimum flow	1	0	20	113		87	31	44	57	2	8	32	7	0		0	0	**402**
Surface water withdrawals	9	1	6	82		27	23	2	8	0	0	2	54	0		0	0	**214**
Ground water withdrawals	4	0	0	98		22	1	10	13	1	0	0	75	0		0	0	**224**
Floods	3	28	0	4		59	0	0	22	1	0	2	12	0		0	0	**131**
Debris flows	0	0	0	0		5	0	0	0	0	0	1	2	0		0	0	**8**
Dams (inundation)	114	38	66	123		95	118	124	104	3	1	19	7	29		0	5	**846**
Stream fragmentation-roads	73	35	136	114		173	85	104	41	4	0	199	8	9		9	2	**992**
In stream/lake habitat	5	6	73	105		156	150	34	104	4	13	53	2	34		0	0	**739**
Riparian habitat	61	7	163	118		216	170	7	171	2	37	190	43	103		0	0	**1288**
Historic Sediment - roads			106						0								1	**107**
Sediment – roads	395	77	203	121		169	161	125	263	4	10	62	45	68		17	79	**1799**
<u>Non-road sediment</u>																		
Historic agriculture	3	0	33	75		40	0	0	10	1	0	1	40	0		0	13	**216**
Agriculture	183	7	138	32		246	79	72	635	1	108	183	91	93		17	74	**1959**
Urbanization	194	3	66	98		176	172	138	276	4	21	14	115	113		16	76	**1482**
Historic forestry	0	0	163	94		34	139	1	39	0	9	33	28	82		0	83	**705**
Forestry	600	40	43	1		156	0	3	199	0	104	4	2	78		6	5	**1241**
Recreation	23	17	5	0		51	0	14	9	2	2	0	0	12		0	11	**146**
Historic grazing	0	0	10	0		0	0	1	4	0	0	1	0	0		0	4	**20**
Grazing	4	0	21	0		144	43	18	123	0	14	174	2	51		0	52	**646**
Mining	11	1	1	1		29	0	7	186	0	30	2	1	13		0	0	**282**
Chemical																		
Low pH-Acid rain	0	38	13	12		27	0	0	154	0	56	33	24	1		1	0	**359**
Low pH-Acid mine drainage	1	0	1	0		0	0	0	178	0	43	0	14	3		0	0	**240**
Dissolved oxygen	8	0	6	1		3	10	0	13	1	1	0	1	0		0	0	**44**
Water temperature – high	124	10	140	99		304	170	120	494	4	6	181	108	0		9	0	**1769**
Water temperature – low	0	1	2	6		8	0	2	0	4	0	0	1	0		0	0	**24**
Eutrophication	7	2	8	5		45	94	27	32	2	0	142	31	0		0	0	**395**

Gas super saturation	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Turbidity	1	0	6	2	36	0	0	7	0	6	167	24	0	0	0	**249**
Heavy metals	2	5	0	3	3	10	0	22	0	0	0	6	0	0	0	**51**
Pesticides	26	0	0	3	36	0	0	1	0	0	130	5	1	0	0	**202**
Historic pesticides	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	**3**
Biological																
All exotics	198	94	148	44	273	23	98	417	2	20	40	45	167	38	87	**1694**
Exotics coldwater																
Rainbow trout	7	73	89	3	64	0	32	18	1	3	38	6	165	37	87	**623**
Brown trout	25	44	129	43	237	23	92	414	0	18	9	43	100	9	26	**1212**
Lake trout	2	1	1	1	4	0	0	1	0	0	0	0	0	0	0	**10**
Landlocked salmon	15	22	2	1	0	0	0	0	0	0	0	0	0	0	0	**40**
Other________	7	3	0	0	6	0	0	0	0	0	0	0	1	0	0	**17**
Exotics cool/warm water																
Smallmouth bass	138	19	11	6	82	12	7	0	0	0	0	3	2	0	0	**280**
Largemouth bass	22	15	3	2	11	0	4	0	1	0	0	0	0	0	0	**58**
Walleye	0	0	1	0	16	0	1	0	0	0	0	0	0	0	0	**18**
Northern pike	7	4	2	1	12	0	0	0	0	0	0	0	0	0	0	**26**
Other___________	36	6	3	0	4	0	0	3	0	0	0	0	0	0	0	**52**
Aquatic weeds	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Over fishing – legal	0	0	0	0	4	0	0	1	0	1	12	0	0	0	0	**18**
Poaching	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Forest pests and disease	1	0	0	0	9	97	0	0	0	0	0	3	5	0	0	**115**
Diseases	1	0	0	0	16	16	1	0	0	0	0	0	0	0	0	**34**
Beavers	276	0	0	79	222	86	9	5	0	0	1	4	0	0	0	**682**
Bird predation	2	0	0	0	56	0	0	0	0	0	0	0	0	0	0	**58**
Historic over fishing	0	0	0	0	14	1	0	0	0	0	0	0	0	0	0	**15**
Historic mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Total	2589	597	1818	1490	3380	1714	1098	4024	44	511	1727	852	1130	159	606	21739

Appendix 3 Table 4. Threats to lakes and ponds

	Category 1 Threats				Category 1+2 Threats				Category 1+2+3 Threats			
Threats:	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**
Physical												
Minimum flow	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**
Surface water withdrawals	0	0	0	**0**	4	0	1	**5**	7	0	1	**8**
Ground water withdrawals	0	0	0	**0**	1	0	0	**1**	1	0	0	**1**
Floods	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Debris flows	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Dams (inundation)	4	3	0	**7**	8	4	1	**13**	11	5	1	**17**
Stream fragmentation (roads)	0	0	0	**0**	2	2	0	**4**	4	4	0	**8**
In stream/lake habitat	0	0	0	**0**	1	2	0	**3**	3	2	0	**5**
Riparian habitat	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**
Sediment – roads	0	0	0	**0**	0	4	0	**4**	128	5	0	**133**
Non-road sediment												
Historic agriculture	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Agriculture	0	0	0	**0**	5	14	0	**19**	27	15	1	**43**
Urbanization	1	0	0	**1**	8	1	2	**11**	51	1	3	**55**
Historic forestry	0	0	1	**1**	0	0	1	**1**	0	0	2	**2**
Forestry	0	0	2	**2**	9	14	17	**40**	191	16	20	**227**
Recreation	0	0	0	**0**	1	0	0	**1**	14	0	0	**14**
Historic grazing	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**
Grazing	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Mining	0	0	0	**0**	1	0	1	**2**	1	0	1	**2**
Chemical												
Low pH -Acid rain	0	0	20	**20**	0	0	22	**22**	0	0	23	**23**
Low pH -Acid mine drainage	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**
Dissolved oxygen	3	0	0	**3**	43	10	1	**54**	68	11	4	**83**
Water temperature – high	1	0	0	**1**	10	11	12	**33**	36	11	12	**59**
Water temperature – low	0	0	0	**0**	2	0	0	**2**	2	0	0	**2**
Eutrophication	2	0	0	**2**	40	7	0	**47**	40	7	0	**47**
Gas super saturation	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Turbidity	0	0	0	**0**	2	1	0	**3**	15	1	0	**16**
Heavy metals	1	0	0	**1**	4	0	0	**4**	4	0	0	**4**
Pesticides	0	0	0	**0**	1	0	0	**1**	8	0	0	**8**

	Category 1 Threats				Category 1+2 Threats				Category 1+2+3 Threats			
Threats:	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**
Historic pesticides	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Biological												
All exotics	13	1	18	**32**	222	30	64	**316**	321	30	65	**416**
Exotics coldwater												
Rainbow trout	0	0	4	**4**	0	13	7	**20**	2	13	7	**9**
Brown trout	3	0	3	**6**	13	7	13	**33**	33	7	13	**46**
Lake trout	0	0	0	**0**	5	2	1	**8**	16	3	1	**17**
Landlocked salmon	1	0	0	**1**	4	5	4	**13**	30	5	6	**36**
Other coldwater exotics	0	0	0	**0**	9	1	1	**11**	28	1	1	**29**
Exotics cool/warm water												
Smallmouth bass	11	0	8	**19**	126	17	40	**183**	206	18	40	**264**
Largemouth bass	9	0	1	**10**	109	7	12	**128**	116	8	12	**136**
Walleye	0	0	1	**1**	0	3	5	**8**	0	3	5	**8**
Northern pike	8	0	3	**11**	13	3	14	**30**	13	3	14	**30**
Other cool/warmwater exotics	6	1	12	**19**	121	15	38	**174**	139	16	38	**193**
Aquatic weeds	0	0	0	**0**	0	3	0	**3**	0	3	0	**3**
Over fishing – legal	1	0	0	**1**	5	0	0	**5**	7	0	0	**7**
Poaching	0	0	0	**0**	1	0	1	**2**	1	0	1	**2**
Forest pests and disease	0	0	0	**0**	1	0	0	**1**	1	0	0	**1**
Diseases	0	0	0	**0**	0	0	0	**0**	2	0	0	**2**
Beavers	1	0	0	**1**	6	0	4	**10**	36	0	7	**43**
Bird predation	0	0	0	**0**	0	0	5	**5**	1	0	5	**6**
Historic over fishing	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**
Total	**65**	**5**	**73**	**143**	**778**	**176**	**267**	**1221**	**1565**	**189**	**283**	**2008**