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

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Abstract. ---- We summarized existing knowledge regarding the distribution and status of self-sustaining 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 support self-sustaining brook trout populations. Brook trout status could not be determined for 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 self-sustaining populations of brook trout were present 45% have lost over 50% of the habitat supporting brook trout (Category: Present: Greatly Reduced); 15 % have lost between 10% and 49% of habitat supporting self-sustaining brook trout (Category: Present: Reduced); 9 % have lost less than 10% of the habitat supporting self-sustaining brook trout (Category: Present: Intact); and 31 % did not have data to determine the percentage of lost habitat (Category: Present: Qualitative data). At the subwatershed level, local fisheries biologists identified high water temperature, agriculture, urbanization, one or more exotic fish species, and poor riparian habitat as the top reasons for the loss of self-sustaining brook trout. 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. Self-sustaining 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 warmwater fishes threaten remaining brook trout populations. Even with no further habitat loss or increase in exotic fishes, existing habitat 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 200 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 perturbations have not been evaluated at a large scale. Evaluations of the integrity of watersheds over the native range of brook trout 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 impaired resources. Our goal is to determine the distribution, status and perturbations to brook trout across a major part of the specie’s range in the eastern United States. Our approach was based on a summary of current knowledge of self-sustaining 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 self-sustaining populations of brook trout, (2) use expert opinion to determine perturbations to self-sustaining 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 of the watershed corridor, and (4) make the database available for a future interactive internet application that uses the classification categories and perturbations 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 with currently available data, (2) it is a level of great interest for land management (McDougal et al. 2001), and (3) it is of a scale 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 unmanageable 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 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. 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

Differences among 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 impossible at the scale of the study area. A least common denominator approach was necessary, even though it eliminated finer scale data that were not available for every subwatershed.

We chose 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 self-sustaining 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 population viability. Self-sustaining populations were not segregated by life history strategy or genetic differences. 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 these data were not available or were 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 (Table 1; Appendix: 1 Table A1). Each couplet in the key was designed to be mutually exclusive with consistent definitions and rules. The benchmark was self-sustaining brook trout populations under historic (pre-European settlement) conditions. We developed several rules to consistently determine the percentages of lost self-sustaining brook trout habitat in each subwatershed. The presence of self-sustaining non-native coldwater fish species within the native range of brook trout (MacCrimmon and Campbell 1969) was considered as evidence that brook trout should have occurred in that habitat (exceptions being coldwater tailwater habitats in previously warmwater streams). Warmwater habitats and transient habitats (which do not support spawning or extended rearing habitat but function only as migration corridors, staging habitats, wintering areas for moving fish) within the watershed were not counted in determining the percentage of habitat supporting self-sustaining brook trout. The following rules were used to consistently determine loss of self-sustaining brook trout habitat:

1) Documented loss of self-sustaining brook trout populations by current or historical reference data.
2) Non-native coldwater species comprise 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 changes in water chemistry (due to acid mine drainage, acid rain, etc.) or water temperature (due to habitat alterations i.e. dams, riparian habitat loss, channelization) that no longer support self-sustaining brook trout.
5) Inundation of brook trout habitat by reservoirs (conversion from coldwater lotic habitat to warmwater lentic habitat)

For consistency the authors made all subwatershed classifications. The classifications were initially based strictly on data provided to the authors, and then again validated with local experts during site visits. Two authors independently validated each classification 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 determine if agreement could be reached. If agreement could not be reached on the subwatershed or data were insufficient to distinguish among classification categories, the watershed was classified as 1.0 Unknown or 4.0 Present: Qualitative. The on-site validation process changed the original classification category from 2% to 30 % of the time. Changes usually resulted from additional data being available or improper interpretation of the original data. 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 classification and 98% of the time after a second review of the key. Most disagreements in classification occurred early in the site visits and dropped dramatically after the local experts became familiar with the key and objectives of the assessment. Separate classifications were made for lotic and lentic habitats when both occurred within the subwatershed.

Perturbations

During the validation site visit, fisheries biologists familiar with the area were asked to list all perturbations and potential 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). Perturbations were characterized as Level 1: high (life cycle component eliminated); Level 2: medium (life cycle component reduced but not eliminated); Level 3: low (general threat, no documented loss or reduction of life cycle). Historic perturbations that are no longer relevant for restoration were designated separately. For example, this category would include a situation where historic forestry eliminated brook trout from a stream, but the area has since been developed into sub-division housing.

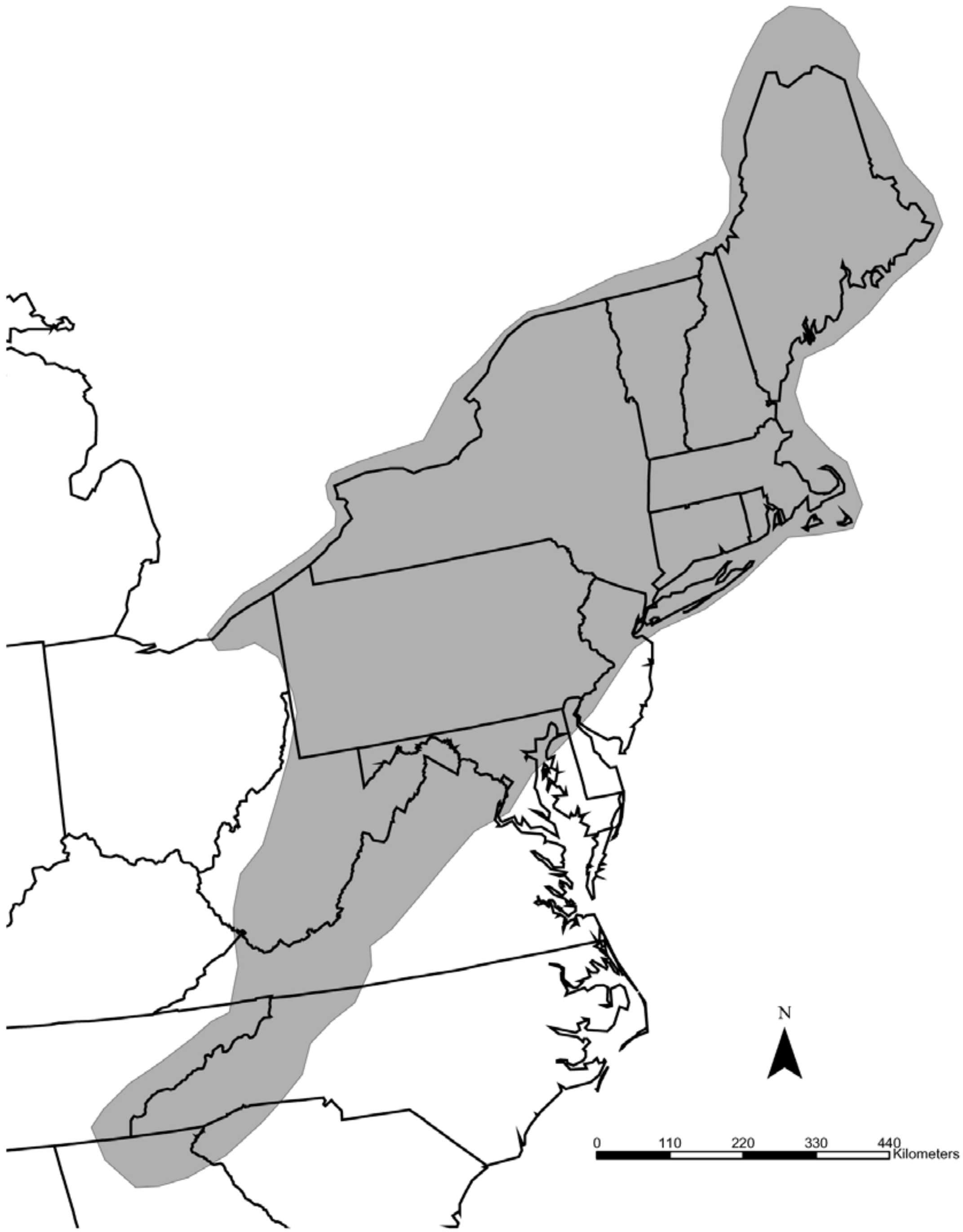

Figure 1. Study Area: Historic range of brook trout in the eastern United States.

Table 1. Summary of watershed level brook trout population classifications and characteristics. See Appendix 1 for specific characteristics, category 6.0 was dropped in final analysis because of small sample size (n = 12).

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; historic status unknown.
Classification 2.0 Never occurred	Historic self-sustaining populations never known to occurr.
Classification 3.0 Extirpated	All historic self-sustaining populations extirpated.
Classification 4.0 Present: Qualitative	No quantitative data; qualitative data show presence.
Classification 5.0 Present: Intact large	High percentage (>90%) of historic habitat occupied by self-sustaining populations, populations greater than 5,000 individuals or 500 adults.
Classification 6.0 Present: Intact small	High percentage (>90%) of historic habitat occupied by self-sustaining populations, populations less than 5,000 individuals or 500 adults.
Classification 7.0 Present: Reduced	Reduced percentage (50% to 90%) of historic habitat occupied by self-sustaining brook trout.
Classification 8.0 Present: Greatly reduced	Greatly reduced percentage (1% to 49%) of historic habitat occupied by self-sustaining brook trout.

Pilot Study Mid-Atlantic Highlands

Because the identification of perturbations was based on professional opinion and was not repeatable, we conducted a pilot study in the Mid-Atlantic Highlands region. This study was based on quantitative, repeatable land use metrics that acted as surrogates for the perturbations identified by expert opinion. We assessed whole watershed and water corridor metrics instead of site-specific variables (Moyle and Randle 1998). Watershed level metrics can provide an indicator of watershed health when many anthropogenic factors may be contributing to a problem and can assist in identification of 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 1.0 Unknown and 4.0 Present: Qualitative) 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 2006.

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. Metrics were obtained 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 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 were 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). Potential 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 30-m 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 was 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 categories associated with presence were combined (Present: Qualitative; 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 one 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 and subwatershed corridor level metrics

General threat	Metric	Description
Sedimentation	RDKM_SQKM	Road kilometers per square kilometer of land
	RDKM_SQKM_C	Road kilometers per square kilometer 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	Percentage 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 Mid-Atlantic pilot study

Results

Lotic distribution and status

Brook trout persist 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 habitat suitable for self-sustaining brook trout populations, or that 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 for 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 self-sustaining populations of brook trout are present, 45% were classified as Present: Greatly reduced (i.e. lost over 50% of the habitat supporting self-sustaining brook trout); 15 % Present: Reduced (i.e. lost between 10% and 49% of habitat supporting self-sustaining brook trout); 9 % Present: Intact (i.e. lost less than 10% of the habitat supporting self-sustaining brook trout; and 31 % Present: Qualitative data (i.e. did not have data to determine the % of self-sustaining 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). The highest percentage of subwatersheds that had Present: Intact or Present: Reduced (i.e. lost less than 50% of habitat that supported self-sustaining 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 brook trout habitat could not be determined (Figure 3, Appendix 2 Figure A2.8 to A2.14).

Lentic distribution and status

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 self-sustaining populations of brook trout. It is not known if brook trout were extirpated or if 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.

Lotic perturbations

Local expert fisheries biologists provided opinions on perturbations that have partially or completely eliminated self-sustaining populations of brook trout within 4,510 subwatersheds. Overall, the top 5 Level 1 perturbations were increased water temperature (20%), agriculture (15%), urbanization (10%), one or more exotic fish species (7%), and degraded riparian habitat (7%)(Table 4). Because many biologists had a difficult time separating Level 1 from Level 2 perturbations at the subwatershed scale we combined them (Table 5). The top five cumulative perturbations (Level 1 and Level 2) were agriculture (36%), increased water temperature (35%), sediment from roads (27%), one or more exotic fish species (26%), and urbanization (25%)(Table 5). When all perturbations (Level 1, Level 2) and threats (Level 3) 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 five perturbations (Table 6). Many of the perturbations (i.e. agriculture, Appendix 3 Figure A3.2) were common throughout the study area while others were concentrated in specific regions. For example exotic fishes and non-native rainbow trout were dominate perturbations in the southeastern states of North Carolina, Tennessee and Georgia (Appendix 3 Figures A3.4 and A3.6). Acid mine drainage was concentrated in the states of Pennsylvania and West Virginia (Appendix 3 Figure 3.12). These geographic differences are reflected in the differences of the state rankings of the top perturbations (Table 4, Table 5, Table 6). The geographic distribution of the top 15 perturbations to brook trout in the eastern United States is summarized in Appendix 3 Figures A3.1 to A3.15. Summaries of individual states perturbations 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	Total Present	Status where present				Presence not documented			
		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

* Subwatershed delineations not available

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.

		Status where present				Presence not documented		
State	**Total Present**	**Present: Qualitative Data**	**Present: Intact**	**Present: Reduced**	**Present: Greatly Reduced**	**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

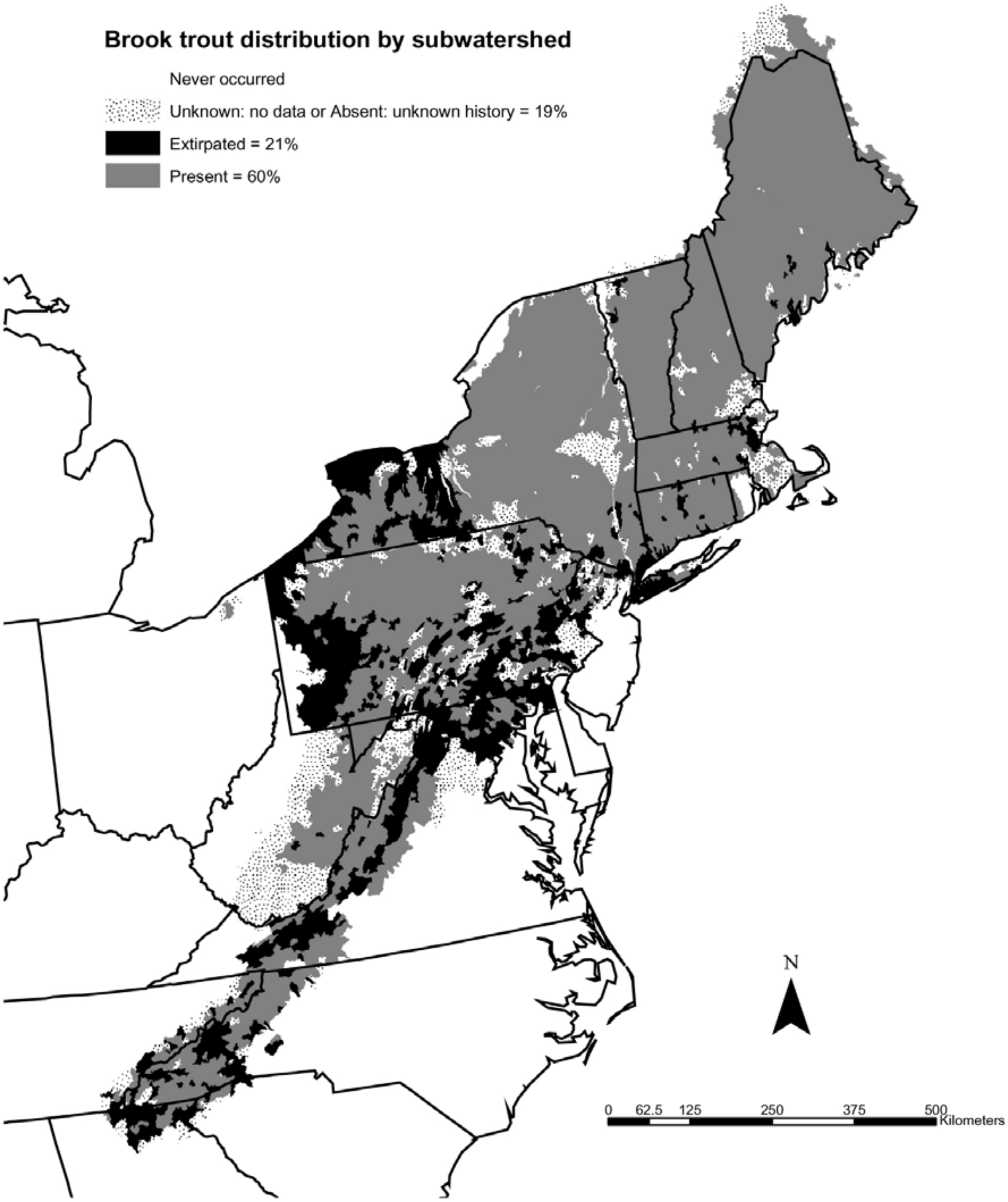

Figure 2. Distribution of subwatersheds in the eastern United States where brook trout are present (60 %), extirpated (21 %) or of unknown status (Unknown: no data and Absent: Unknown history) (19 %). Subwatersheds classified as Never occurred are not included in the percentage calculations.

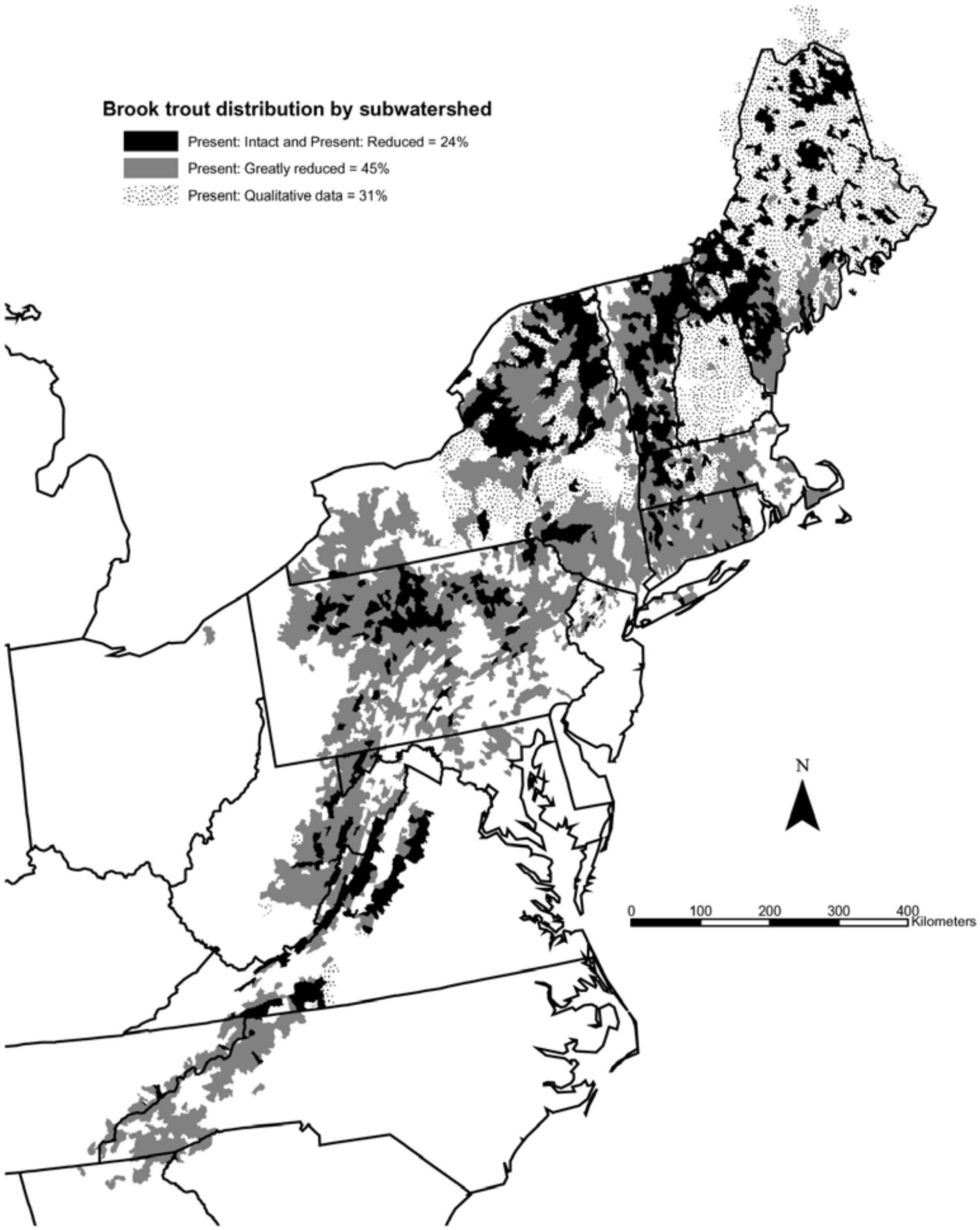

Figure 3. Subwatersheds containing brook trout in the eastern United States. Subwatersheds with Present: Intact and Present: Reduced (24 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced (45 %) classifications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

Lentic perturbations

Local fisheries biologists provided opinion on perturbations that have partially or completely eliminated self-sustaining populations of brook trout within lakes and ponds on 1,324 subwatersheds in the states of Maine, New York, and Vermont, the only states with appreciable amounts of self-sustaining brook trout lakes and ponds. Overall, one or more exotic fish species, low pH from acid rain and a specific exotic fish, the smallmouth bass, were the top 3 Level 1 perturbations. When Level 1 perturbations were combined with Level 2 perturbations all exotic species, smallmouth bass, other cool/warmwater species, largemouth bass and dissolved oxygen were the top 5 cumulative perturbations (Table 7). When Level 1, Level 2 perturbations and Level 3 threats were combined one or more exotic fish species, smallmouth bass and forestry were the top 3 perturbations (Table 7).

In the cumulative rankings of Level 1 and Level 2 lentic perturbations Maine, New York, and Vermont had exotic species in their top 3 perturbations. 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 perturbations.

Summaries of individual states perturbations by Level 1, cumulative Level 1 and Level 2, and cumulative Level 1, Level 2, and 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: (Present: Intact 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 correctly predicting pairings of the three groups 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 Figure 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 percentage total human land use, percentage evergreen forest, percentage deciduous forest in the water corridor, and the percentage 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 percentage 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 resulted from 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 specie's native range in the United States (MacCrimmon and Campbell 1969). Although not currently threatened with extinction across the entire range, brook trout were extirpated from 21% and greatly reduced in 27% of the subwatersheds in the study. Many of the subwatersheds that were greatly reduced contained only one or two small populations of brook trout restricted to isolated headwater habitats. These subwatersheds lacked the redundancy and connectivity to reestablish populations and therefore are especially prone to extirpation of brook trout due to increased human land use impacts or natural stochastic events.

Many extirpations and reductions in suitable brook trout habitat occurred at the turn of the last century as a result of logging and agricultural practices. Construction of over 75,000 dams (USCOE 1998), and 2 million miles of roads (Navtech 2001), as well as an increase of 90 million residents (U.S. Census Bureau 2002) have occurred in the study area over the last 100 years. This has led to dramatic land use changes; now over 30 % of the average subwatershed is in land uses classified as human land uses (USGS 2002a). This last 100 years has also been a period of dramatic change in distribution of fish species 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 contained predominately brook trout. Local extirpations of brook trout in New Hampshire ponds and lakes caused by the introduction of chain pickerel *Esox niger* have been documented as early the 1890's (Noon 2003). However, local extirpations are not limited to historical activities and continue today. The biologists data showed many subwatersheds have had recent losses (within the last ten years) of self-sustaining populations of brook trout. Many of the perturbations 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 perturbations for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 perturbations (duplicate numbers indicate ties in rankings).

Rank	Perturbations:	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 perturbations and Category 2 medium level perturbations for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 perturbations (duplicate numbers indicate ties in rankings).

Rank	**Perturbations:**	**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	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 perturbations, Category 2 medium level perturbations and Category 3 low level perturbations for subwatersheds (n = 4,484) within the brook trout range in the eastern United States. State values are rankings of the top 5 perturbations (duplicate numbers indicate ties in rankings).

Rank	**Perturbations:**	**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 perturbations (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 perturbations (duplicate numbers indicate ties in rankings).

Lakes and Ponds	**ME**	**VT**	**NY**			**Lakes and Ponds**	**ME**	**VT**	**NY**			**Lakes and Ponds**	**ME**	**VT**	**NY**	
Category 1 Threat	**Rank**	**Rank**	**Rank**	**TOT #**	**Rank**	**Categories 1+2 Perturbations**	**Rank**	**Rank**	**Rank**	**TOT #**	**Rank**	**Categories 1+2+3 Perturbations**	**Rank**	**Rank**	**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**

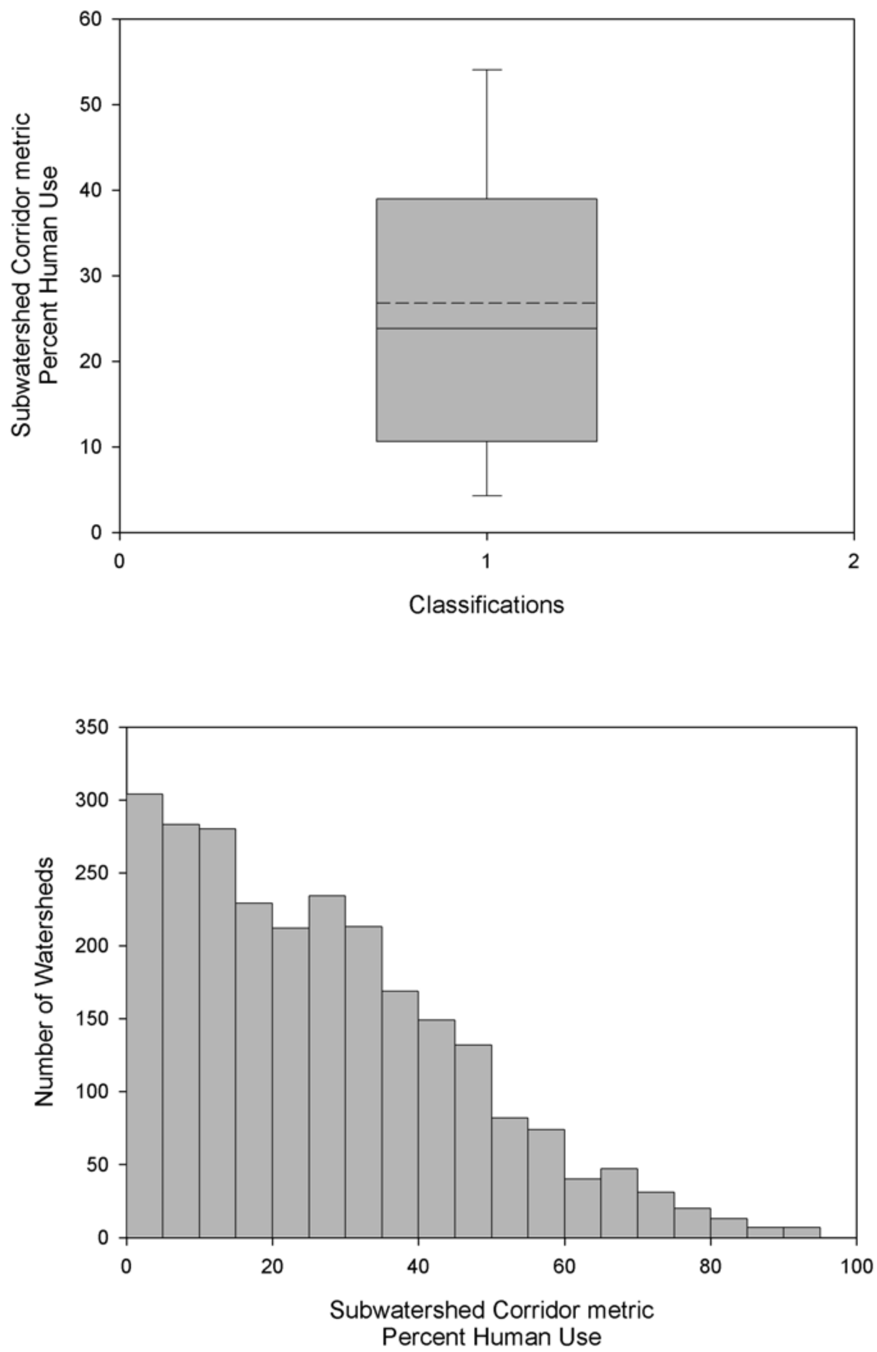

Figure 4. Distribution of the percentage of total human uses by subwateshed. Solid line is the median, dashed line is the mean (N = 4,484).

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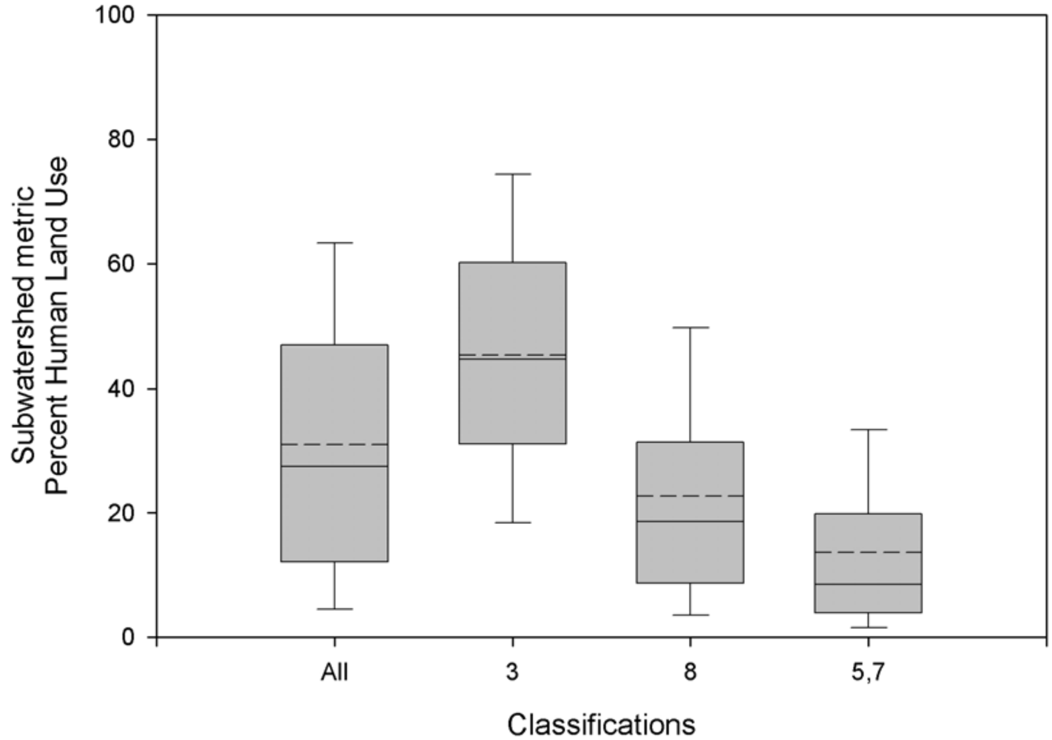

Figure 5. Distribution of the percentage of total human land uses by brook trout classification category. All = all classifications; 3 = extirpated; 8 = Present: Greatly reduced; 5 = Present: Intact; 7 = Present: Reduced. Solid line is the median; dashed line is the mean (N = 4,484).

Our pilot study in the Mid-Atlantic region showed that human land uses were good predictors of 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 that 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 habitat fragmentation.

Many subwatersheds (33 %) had inadequate information (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 Maine and New Hampshire, which are brook trout strongholds. 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 neither been published or subject to peer review and despite criteria provided for classification there was an element of subjectivity. It was 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, 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 self-sustaining populations.
2. Southern most states (SC,NC,TN,GA) have lost almost all Present: Intact populations.
3. Important quantitative data gaps 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 two perturbations 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 been all but 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 self-sustaining brook trout in the 6th level sub-watershed. **Classification 1.0 (Unknown).**

1b. Quantitative or qualitative databases exist that document presence or absence of self-sustaining populations of brook trout; **go to question 2**

2a. Quantitative and /or qualitative databases document that there are no self-sustaining 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 self-sustaining brook trout populations; **go to question 3**

3a. Quantitative and/or qualitative databases support that self-sustaining 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 self-sustaining coldwater 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 self-sustaining 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 self-sustaining, currently self-sustaining) 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 self-sustaining 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).**

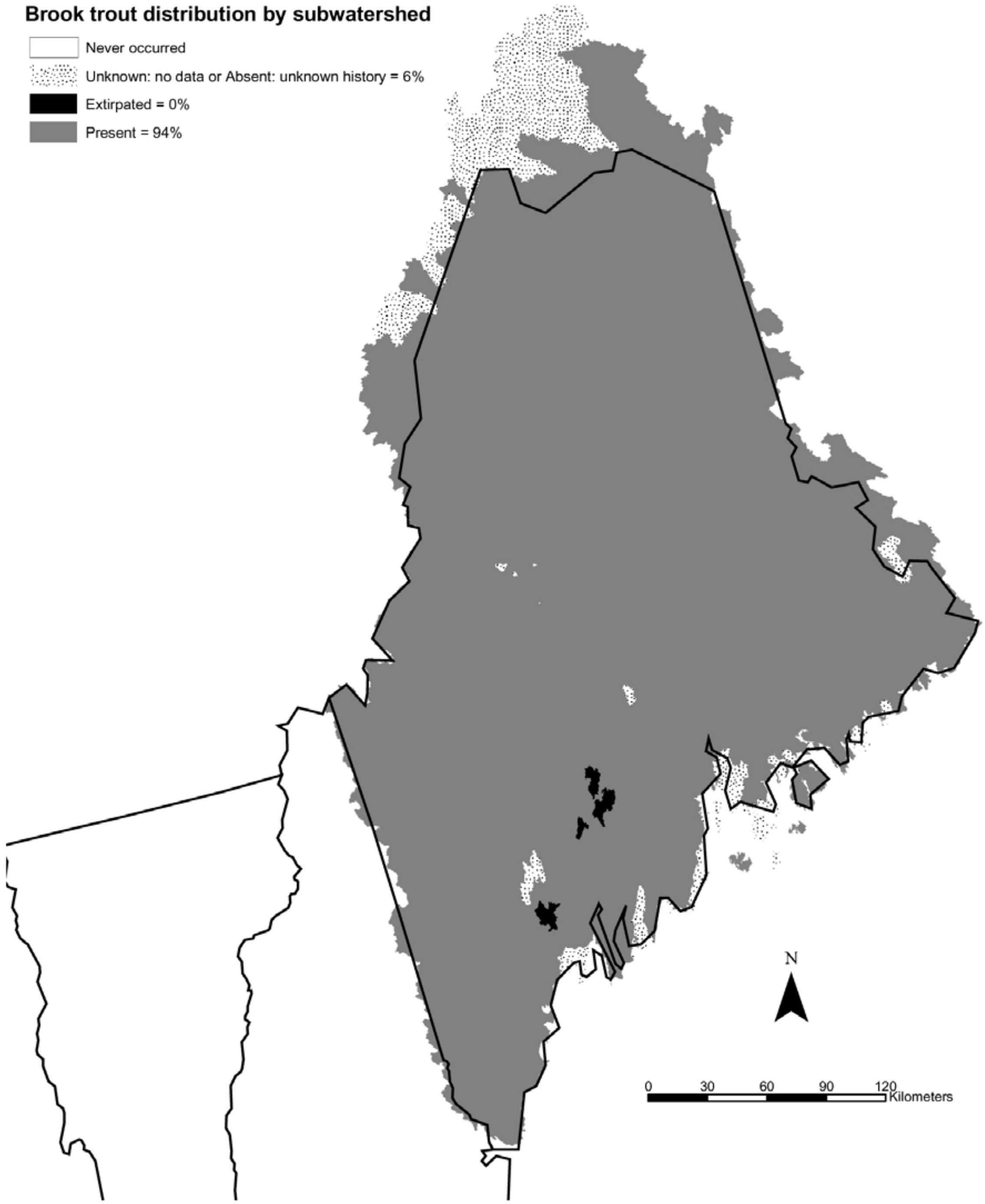
8a. Between 50% and 90% of historic occupied lotic habitats within the entire 6th level sub-watershed support self-sustaining brook trout populations; **Classification 7.0 (Present: Reduced).**
8b. Between 1% and 49% of historic occupied lotic habitats within the entire 6th level sub-watershed support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

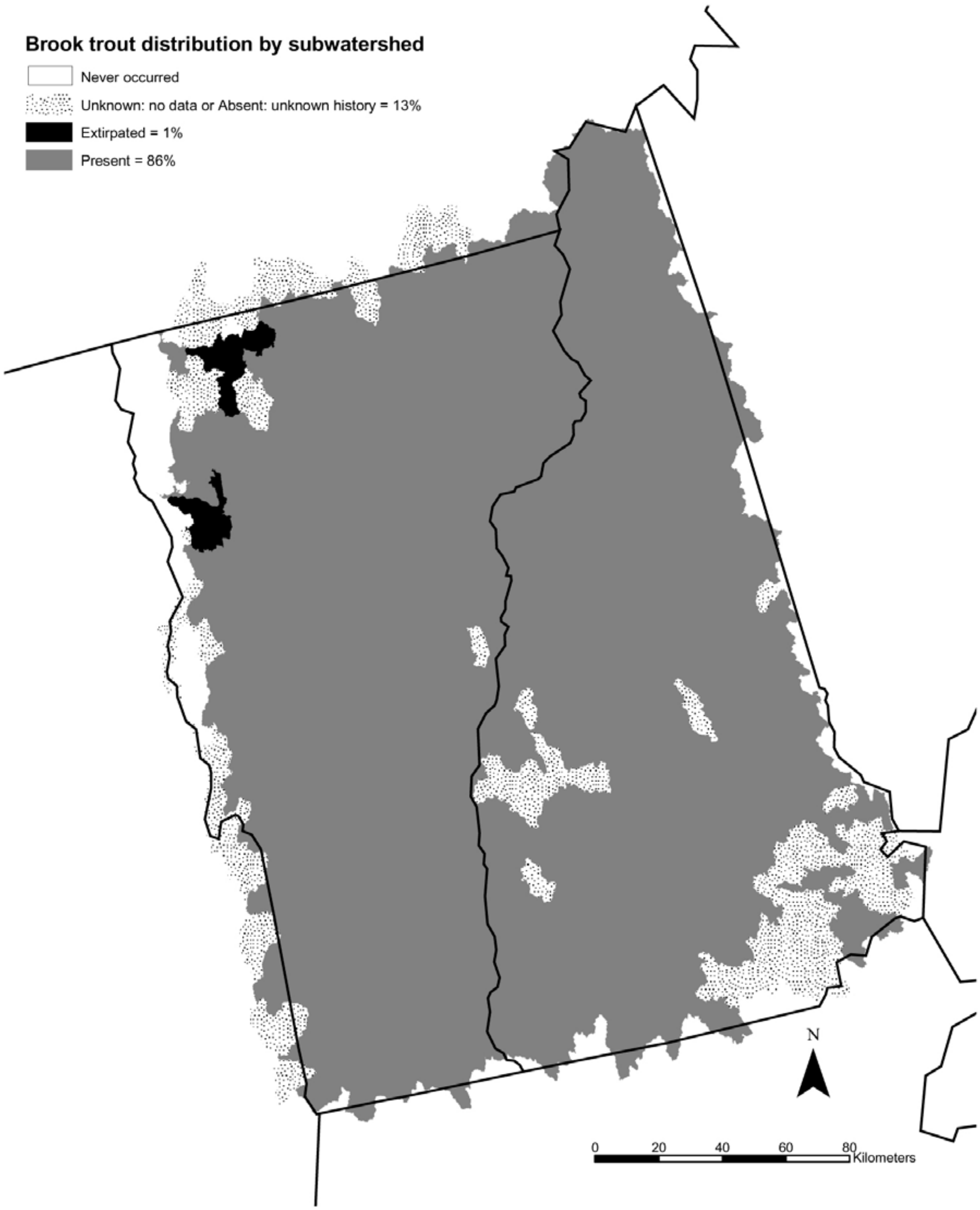
1. Documented loss of self-sustaining populations by current or historical data
2. Only exotic coldwater species self-sustaining within native range of brook trout
3. Coldwater exotic species greater than 75% of coldwater biomass or numbers
4. Brook trout carrying capacity reduced by greater than 90%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

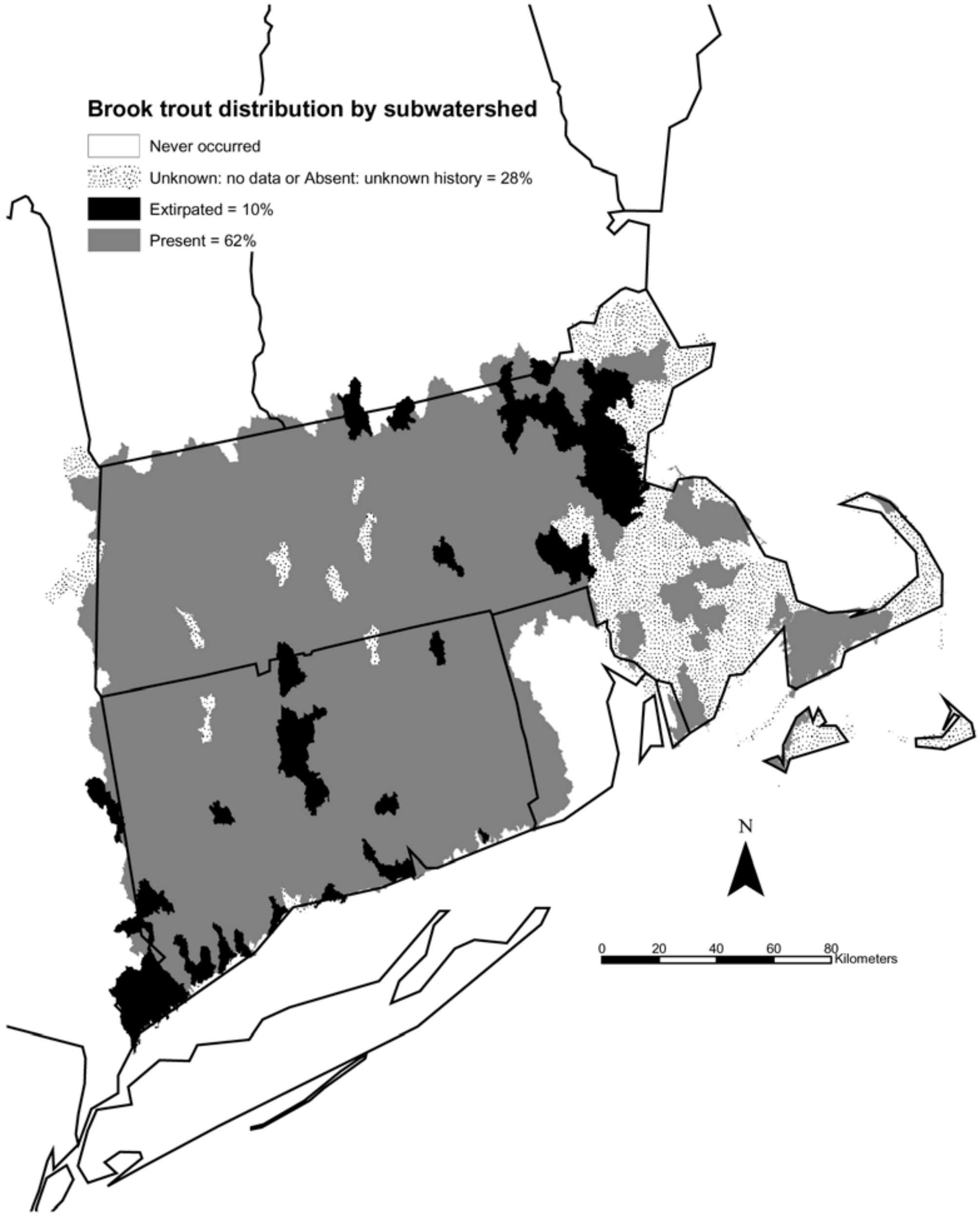
Watershed code:	Lotic Habitats	Lentic habitats
Physical		
Minimum flow		
Surface water withdrawals		
Ground water withdrawals		
Floods		
Debris flows		
Stream fragmentation dams		
Stream fragmentation (road crossings, culverts)		
In stream/lake habitat		
Riparian habitat		
Sediment – roads		
Non-road 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- coldwater		
Rainbow trout		
Brown trout		
Lake trout		
Landlocked salmon		
Other____________		
Exotics cool/warmwater		
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		



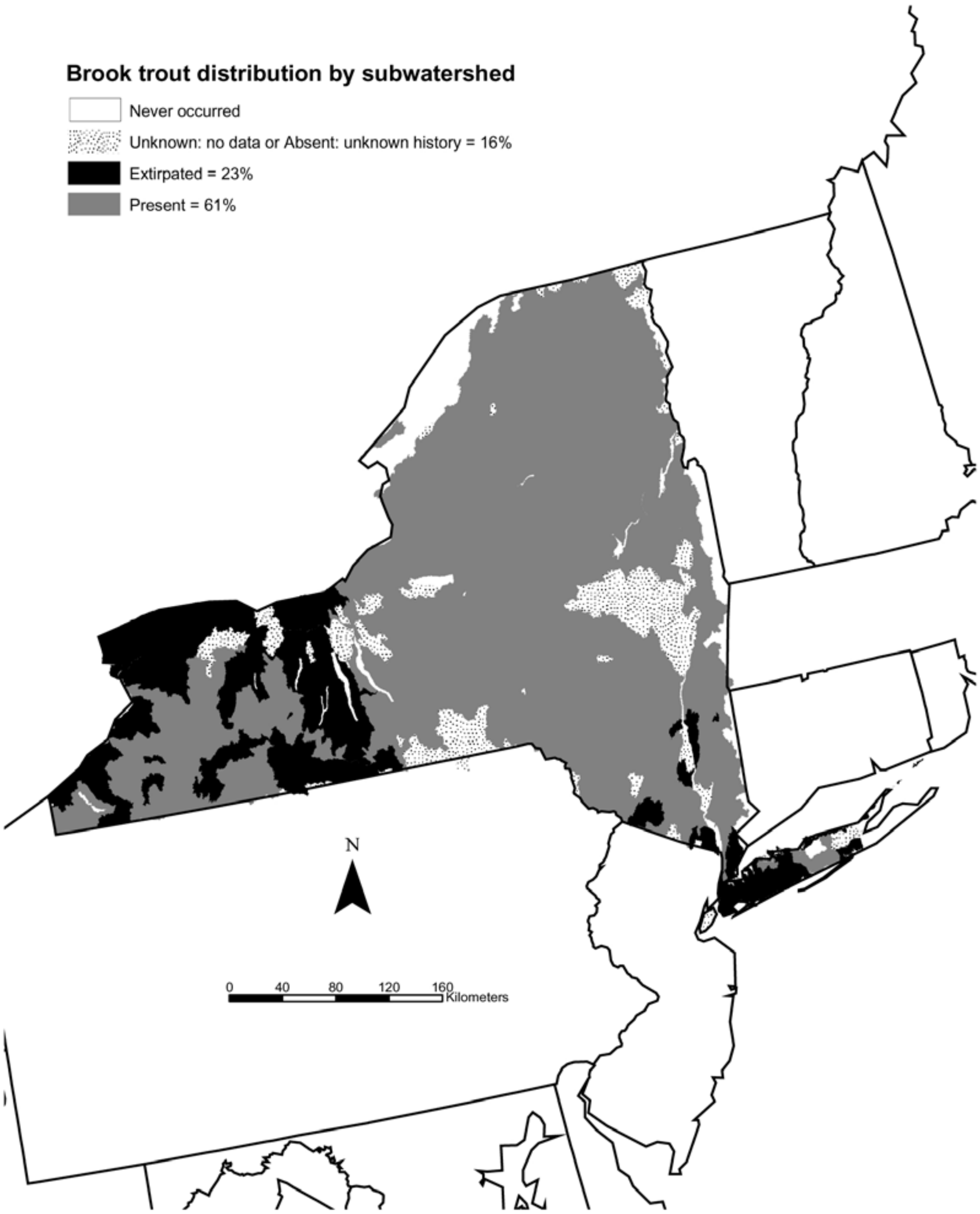
Appendix 2 Figure A2.1. Distribution of subwatersheds in the Maine where brook trout are present (94 %), extirpated (0 %) or of unknown status (Unknown: no data and Absent: Unknown history) (6 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



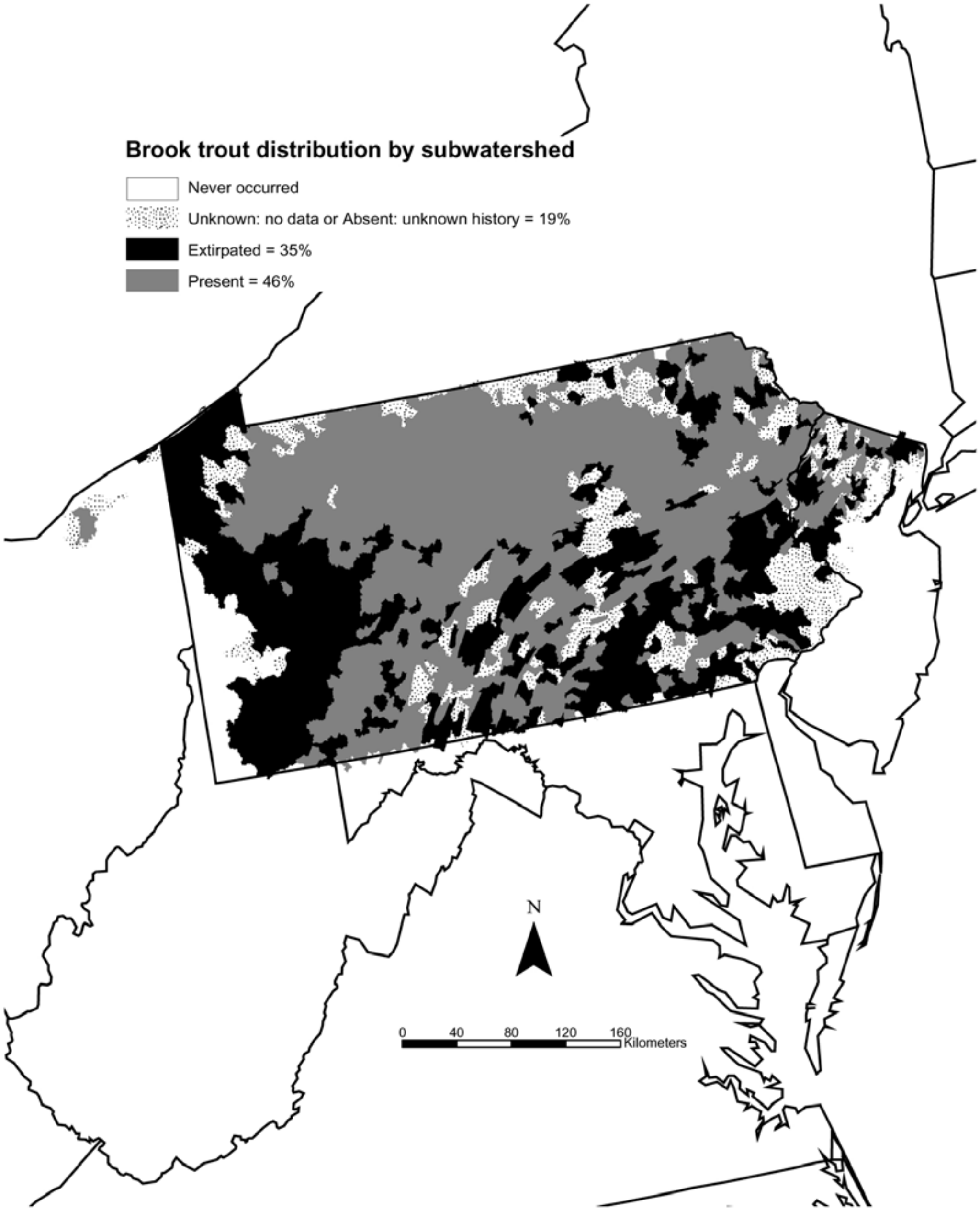
Appendix 2 Figure A2.2. Distribution of subwatersheds in New Hampshire and Vermont where brook trout are present (86 %), extirpated (1 %) or of unknown status (Unknown: no data and Absent: Unknown history) (13 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



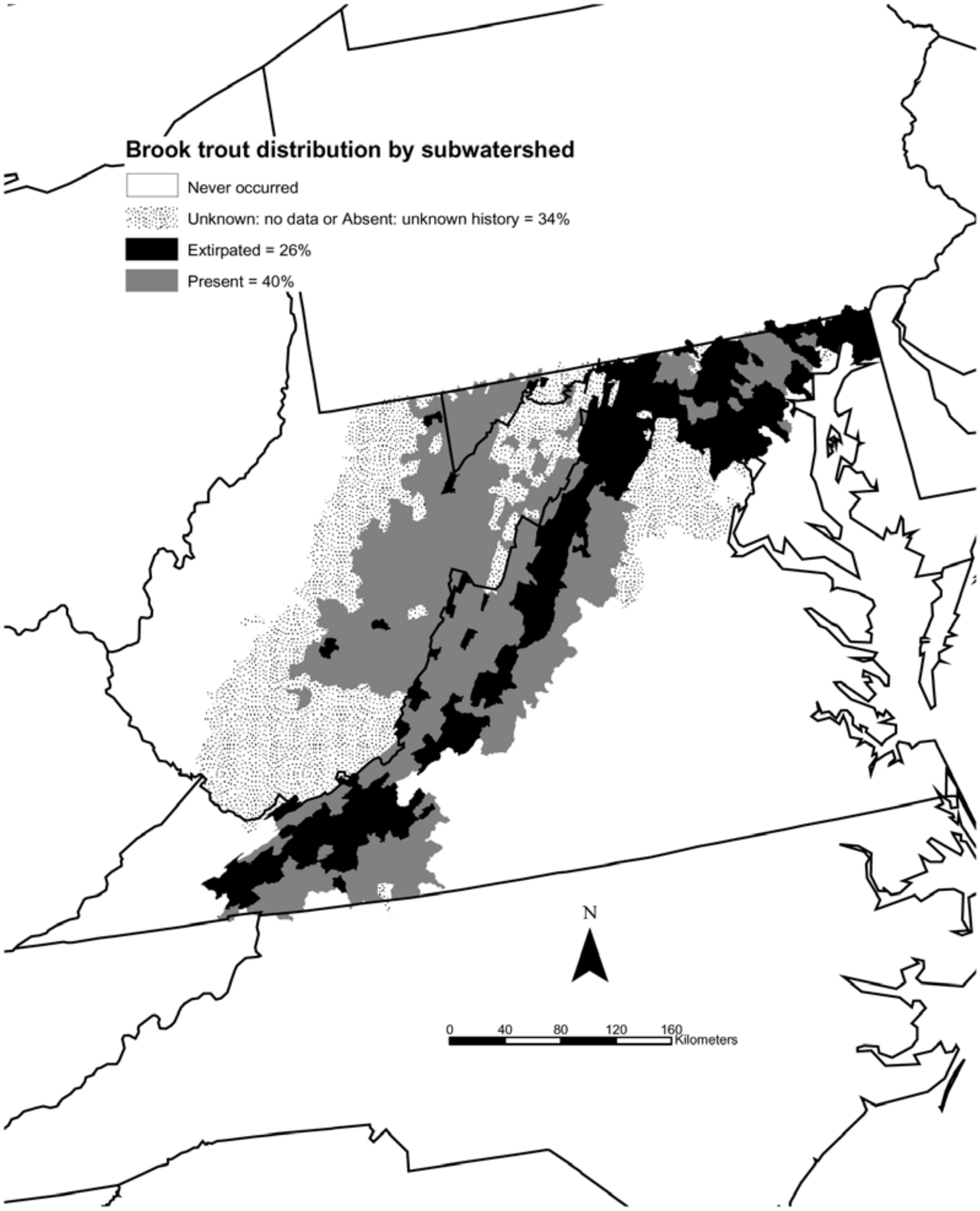
Appendix 2 Figure A2.3. Distribution of subwatersheds in Massachusetts, Connecticut, and Rhode Island where brook trout are present (62 %), extirpated (10 %) or of unknown status (Unknown: no data and Absent: Unknown history) (28 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



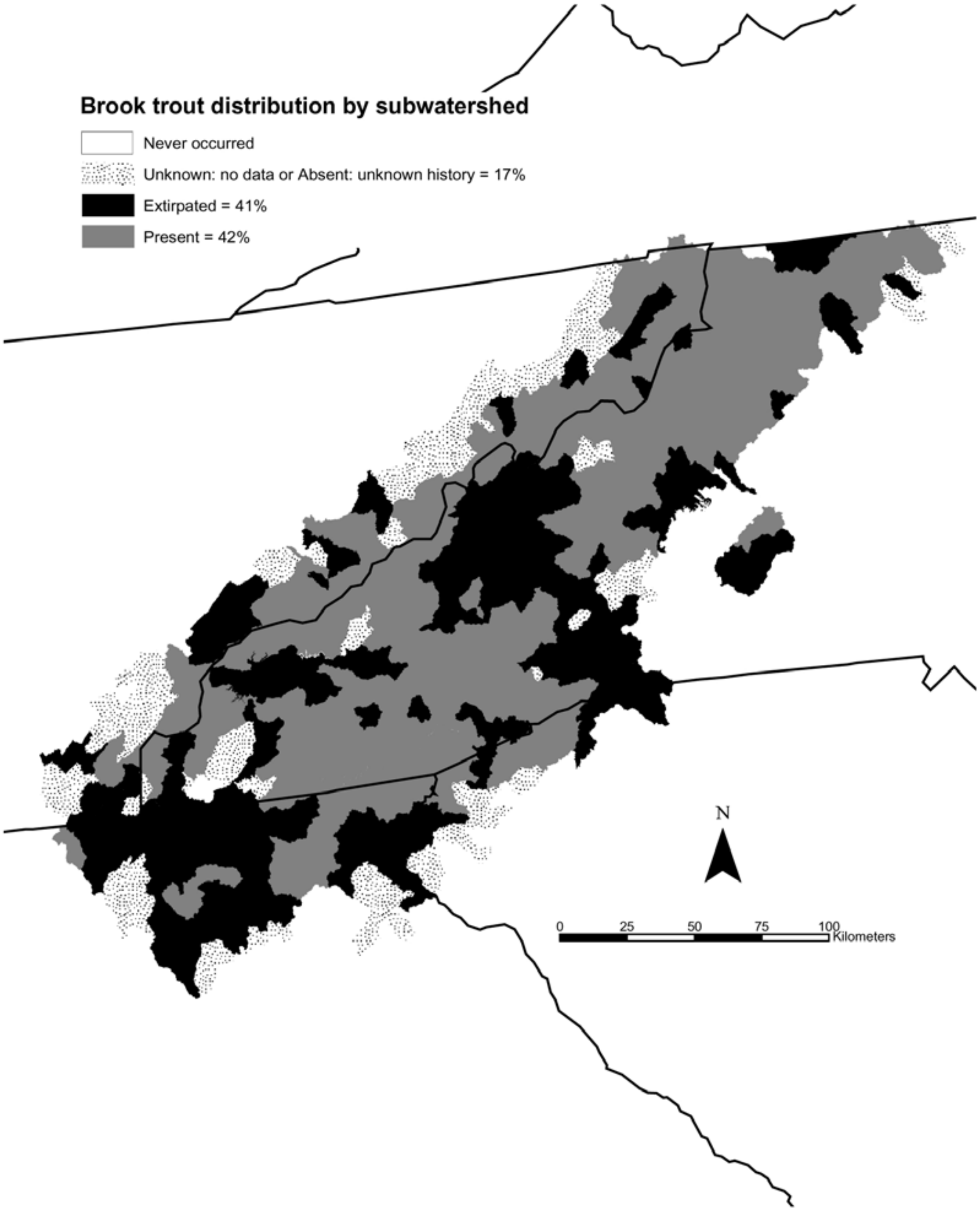
Appendix 2 Figure A2.4. Distribution of subwatersheds in New York where brook trout are present (61 %), extirpated (23 %) or of unknown status (Unknown: no data and Absent: Unknown history) (16 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



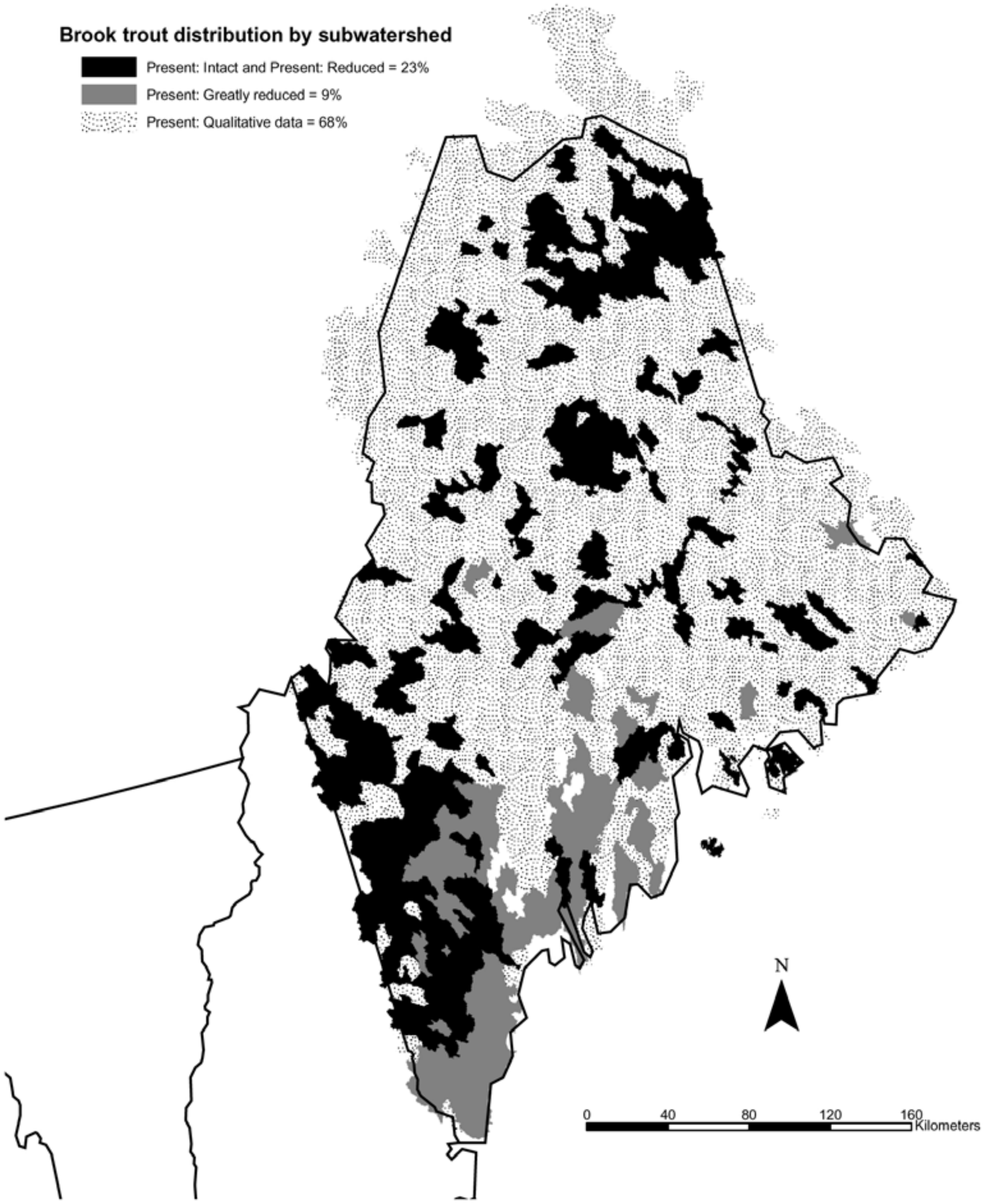
Appendix 2 Figure A2.5. Distribution of subwatersheds in Pennsylvania and New Jersey where brook trout are present (46 %), extirpated (35 %) or of unknown status (Unknown: no data and Absent: Unknown history) (19 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



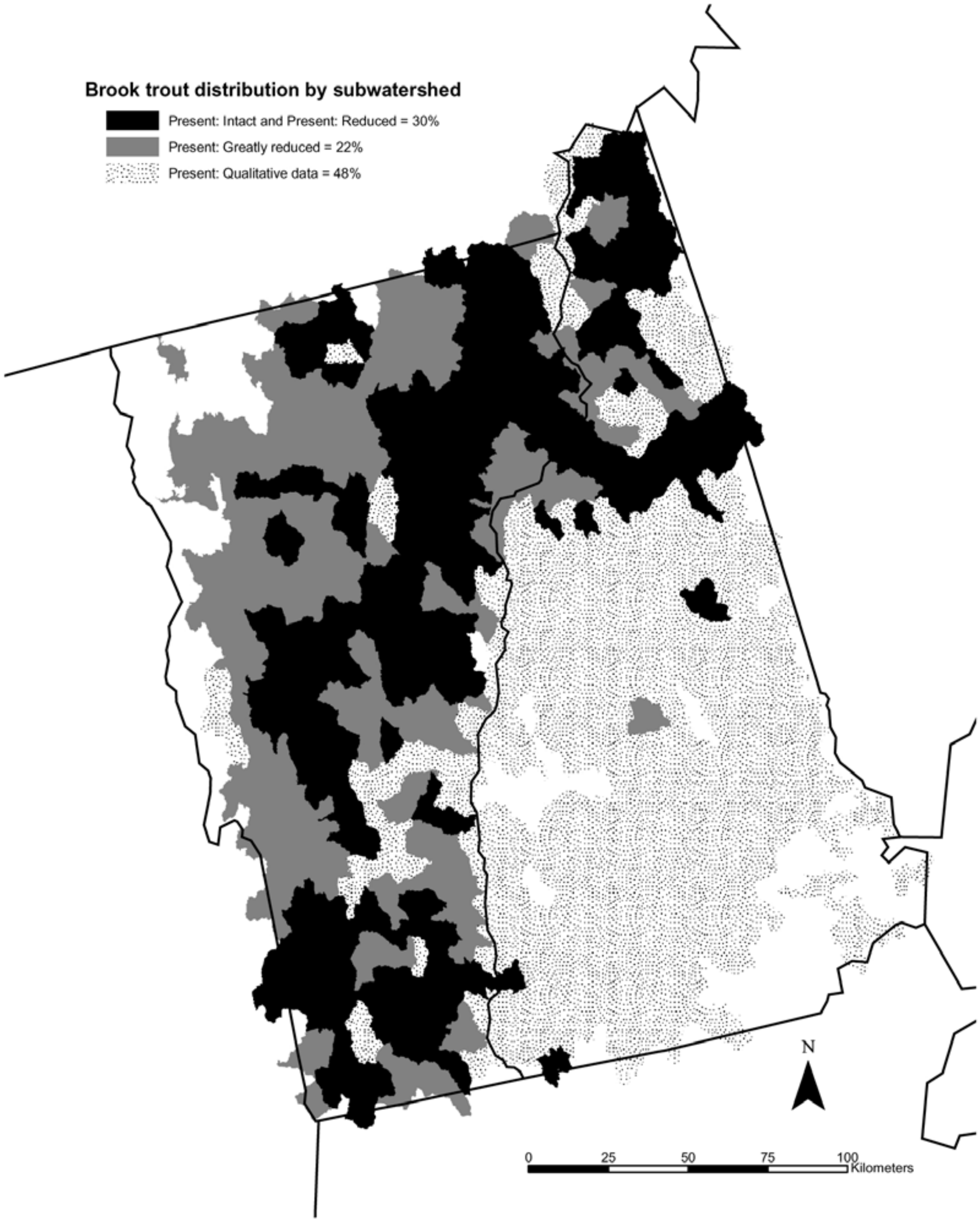
Appendix 2 Figure A2.6. Distribution of subwatersheds in Maryland, West Virginia and Virginia where brook trout are present (40 %), extirpated (26 %) or of unknown status (Unknown: no data and Absent: Unknown history) (34 %). Subwatersheds classified as never occurred are not included in the percentage calculations.



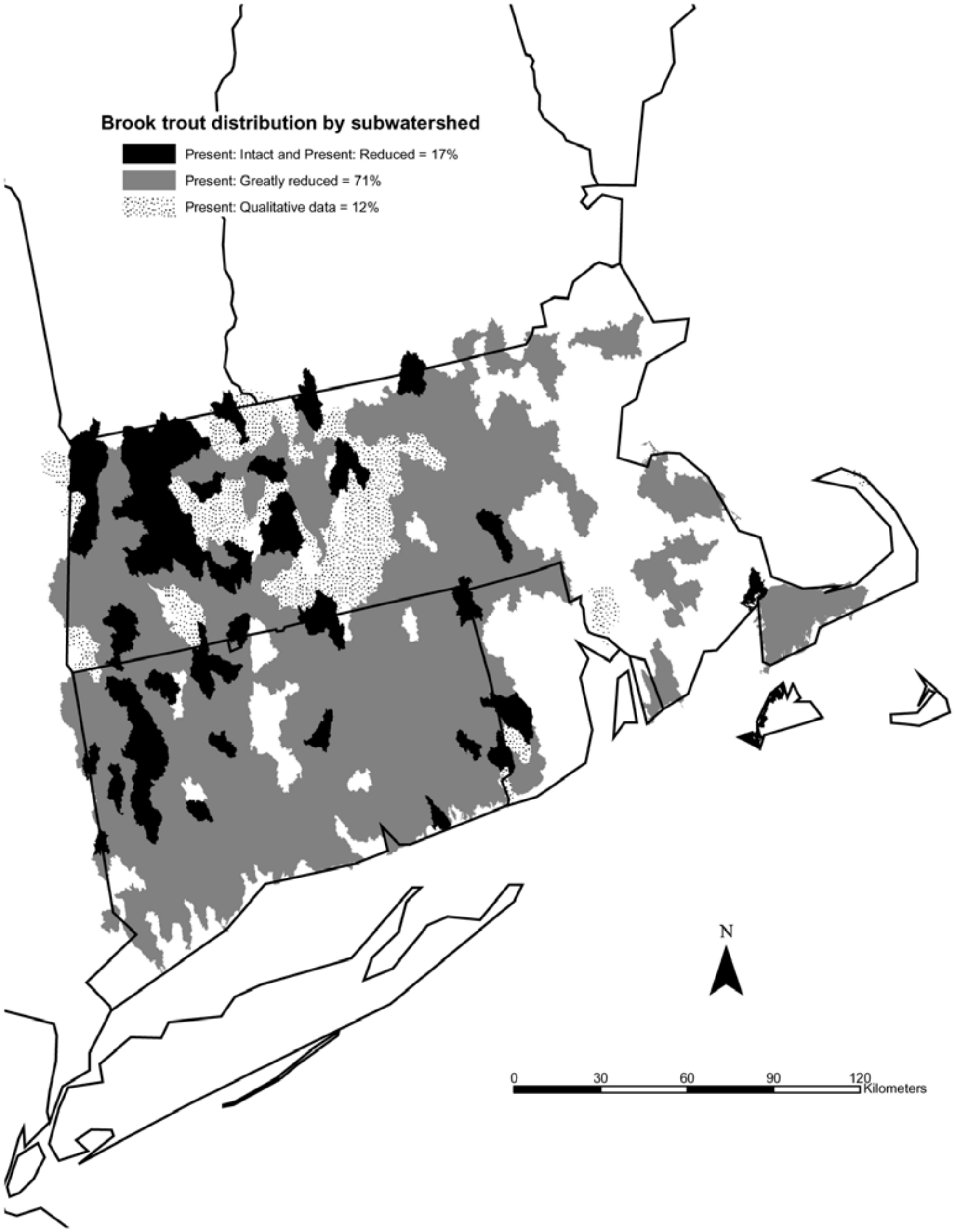
Appendix 2 Figure A2.7. Distribution of subwatersheds in North Carolina, South Carolina, Tennessee and Georgia where brook trout are present (42 %), extirpated (41 %) or of unknown status (Unknown: no data and Absent: Unknown history) (17 %). Subwatersheds classified as never occurred are not included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



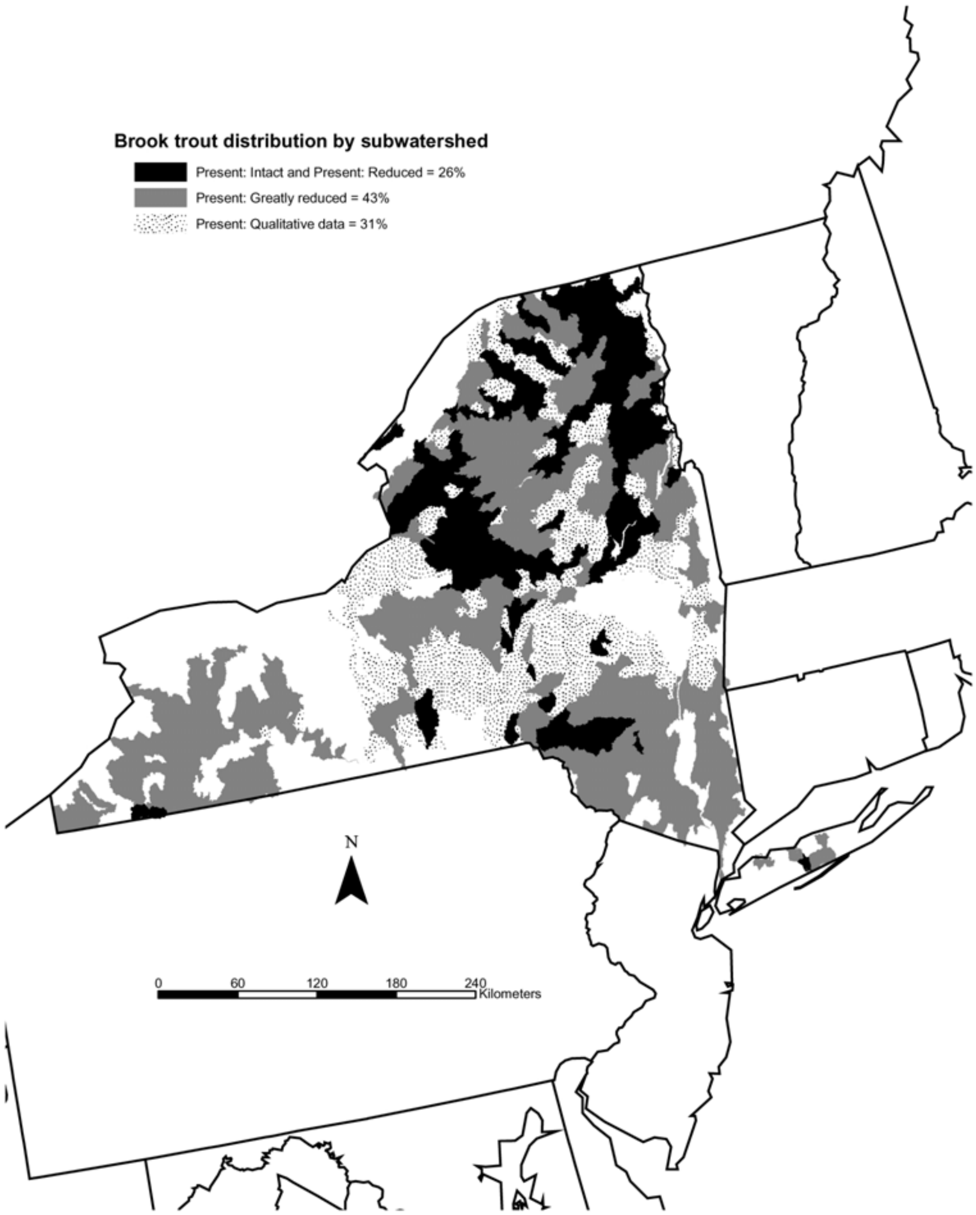
Appendix 2 Figure A2.8. Subwatersheds containing brook trout in Maine. Subwatersheds with Present: Intact and Present: Reduced (23 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced (9 %) classifications have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



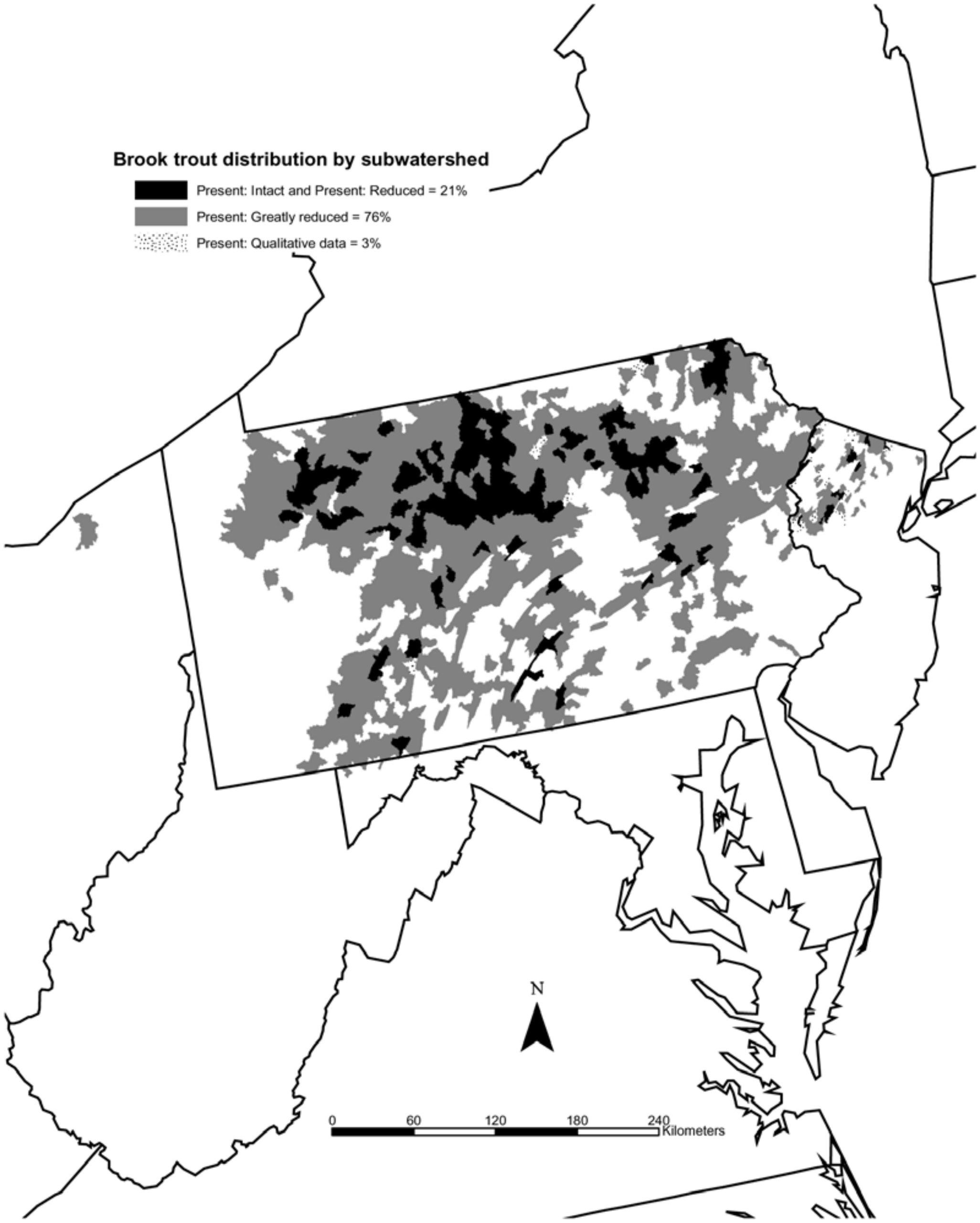
Appendix 2 Figure A2.9. Subwatersheds containing brook trout in New Hampshire and Vermont. Subwatersheds with Present: Intact and Present: Reduced (30 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced (22 %)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



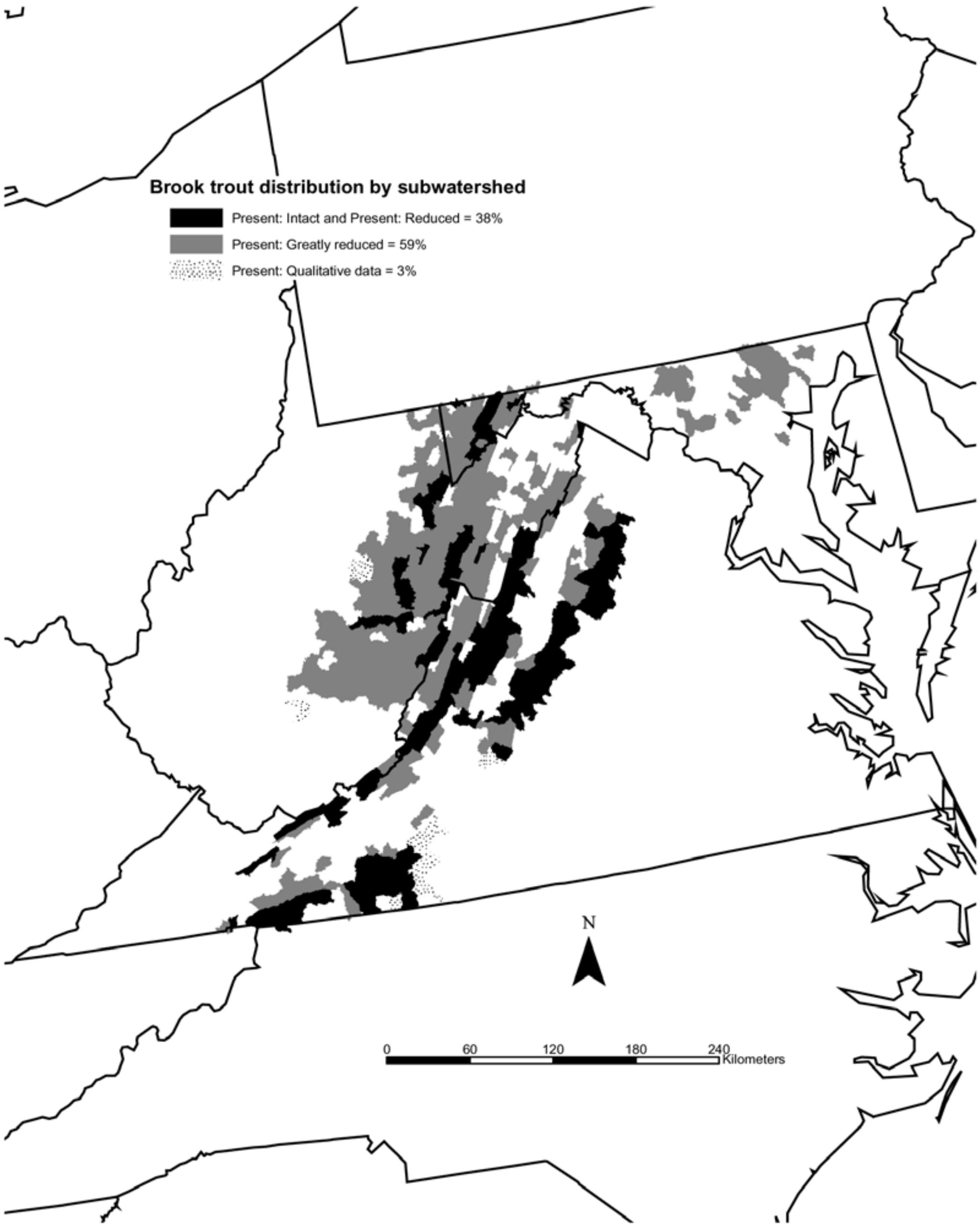
Appendix 2 Figure A2.10. Subwatersheds containing brook trout in Massachusetts, Connecticut, and Rhode Island. Subwatersheds with Present: Intact and Present: Reduced (17 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly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



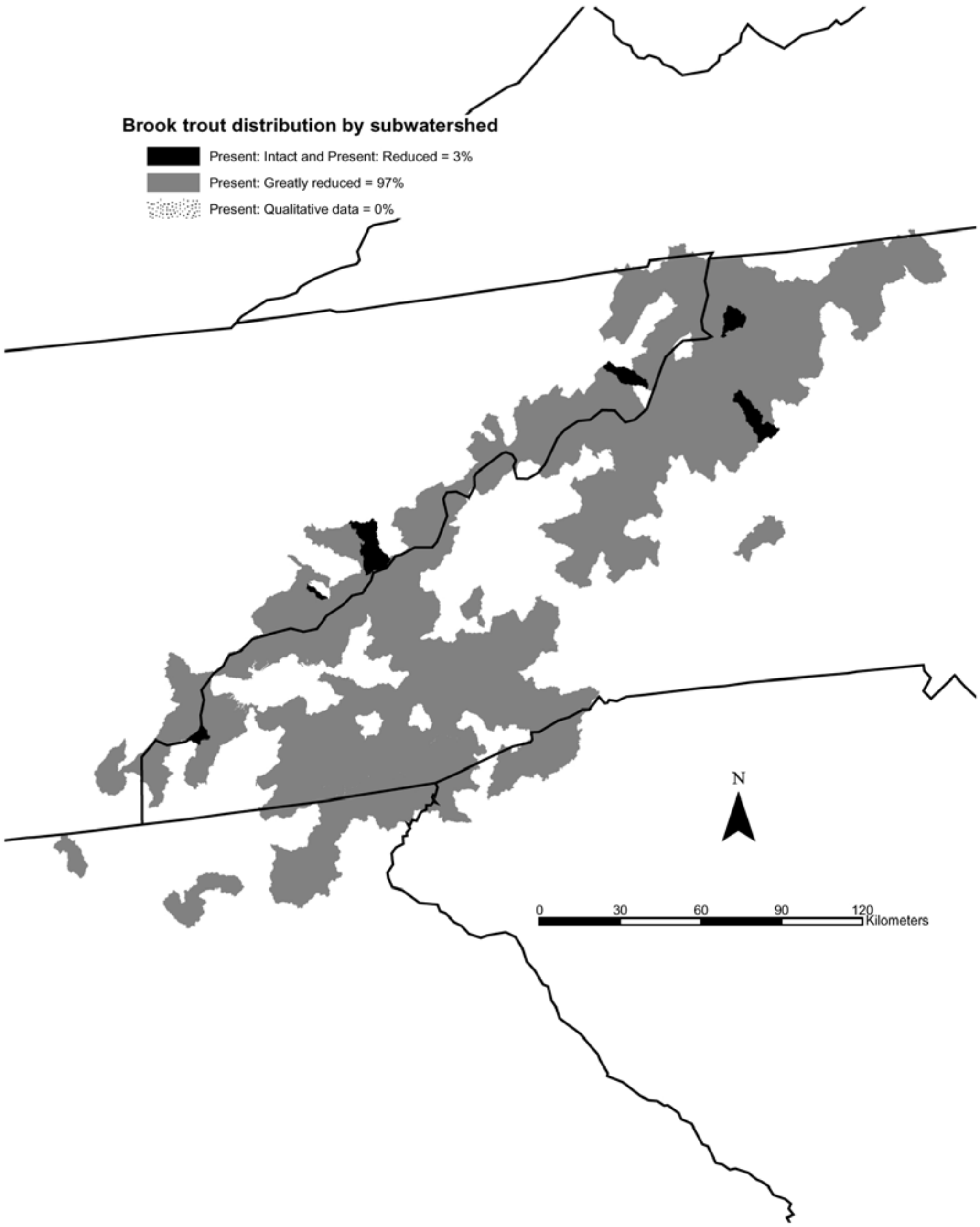
Appendix 2 Figure A2.11. Subwatersheds containing brook trout in New York. Subwatersheds with Present: Intact and Present: Reduced (26 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced (43 %) classifications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



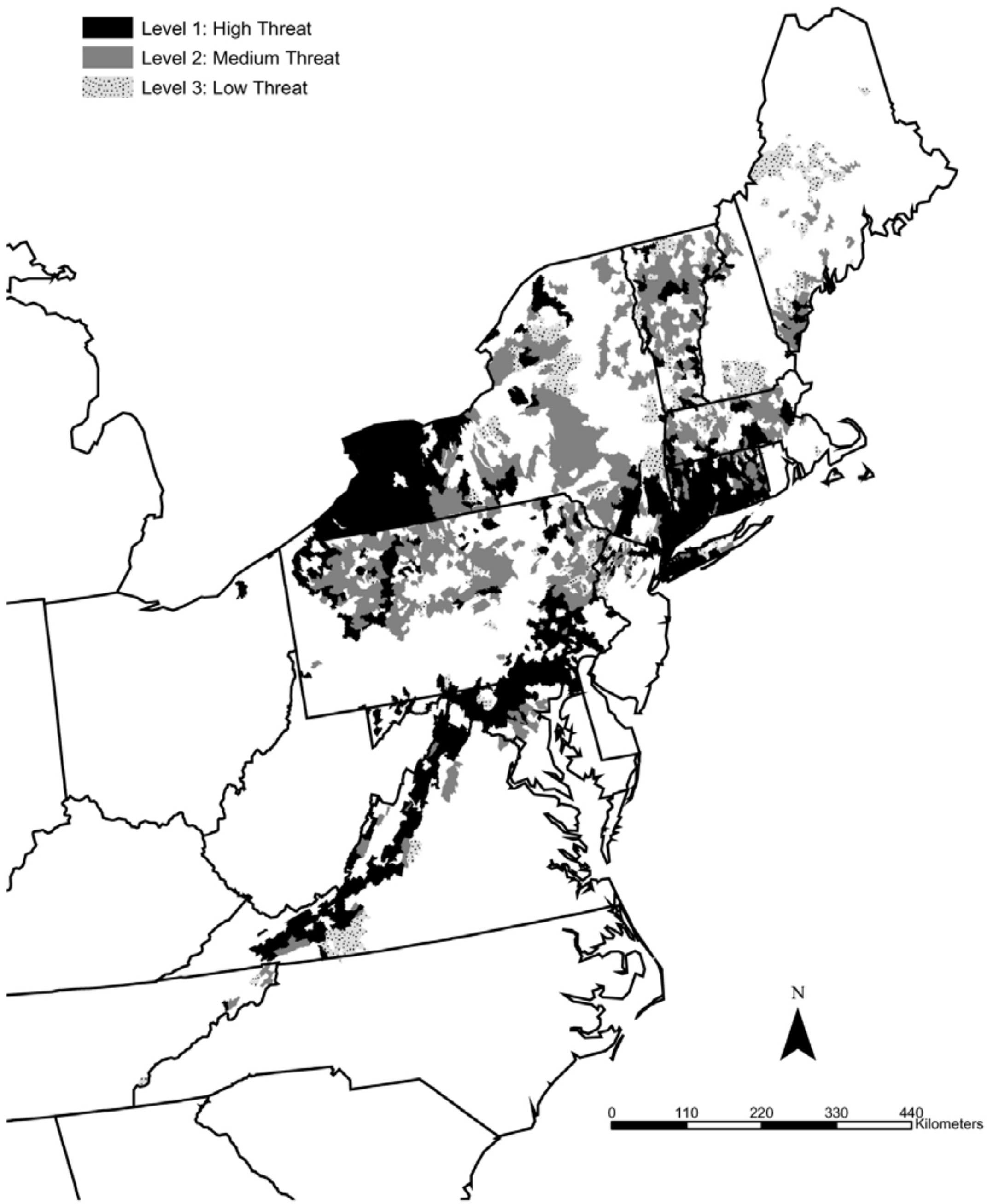
Appendix 2 Figure A2.12. Subwatersheds containing brook trout in Pennsylvania and New Jersey. Subwatersheds with Present: Intact and Present: Reduced (21 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced (76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



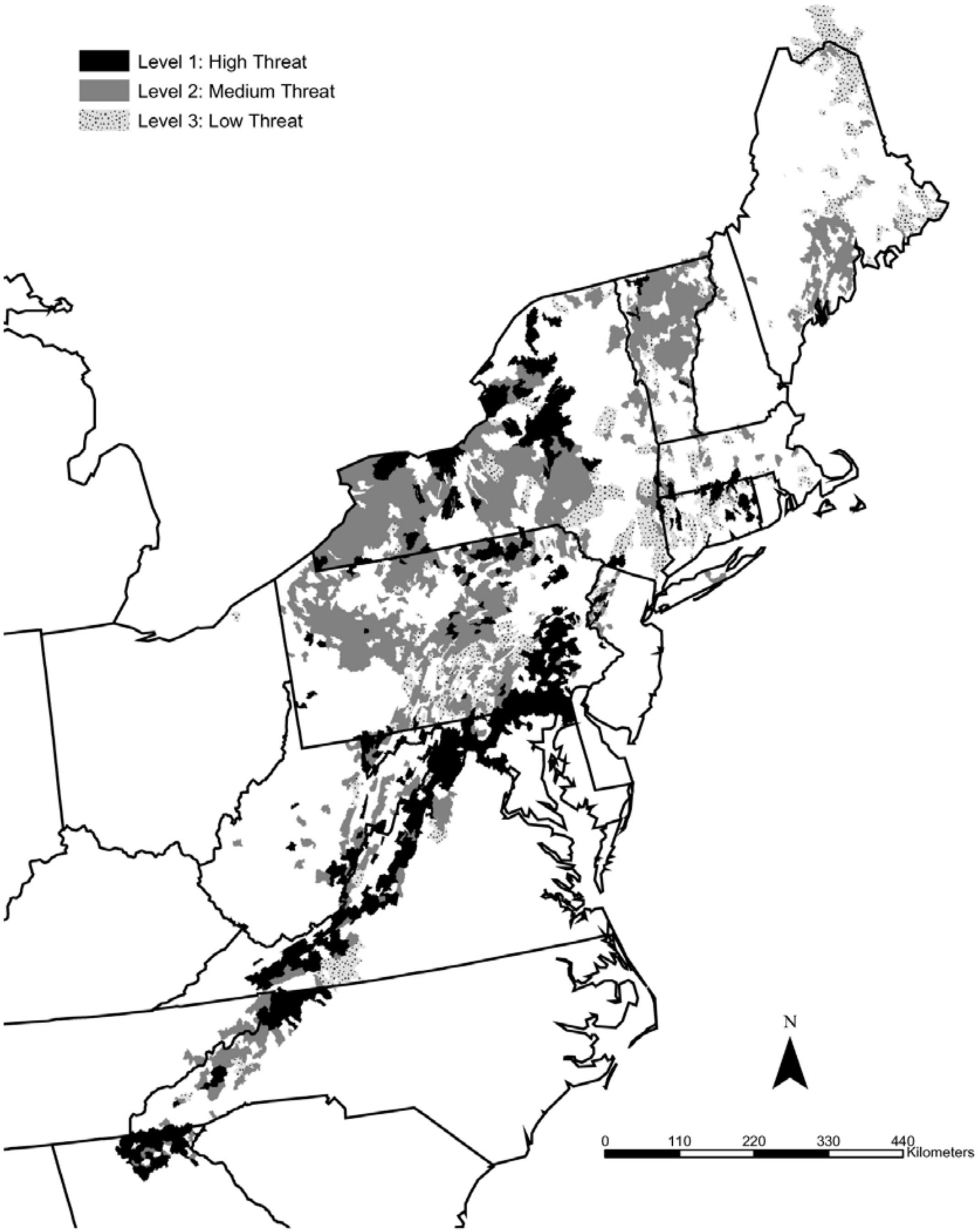
Appendix 2 Figure A2.13. Subwatersheds containing brook trout in West Virginia, Maryland and Virginia. Subwatersheds with Present: Intact and Present: Reduced (38 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: Greatly reduced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



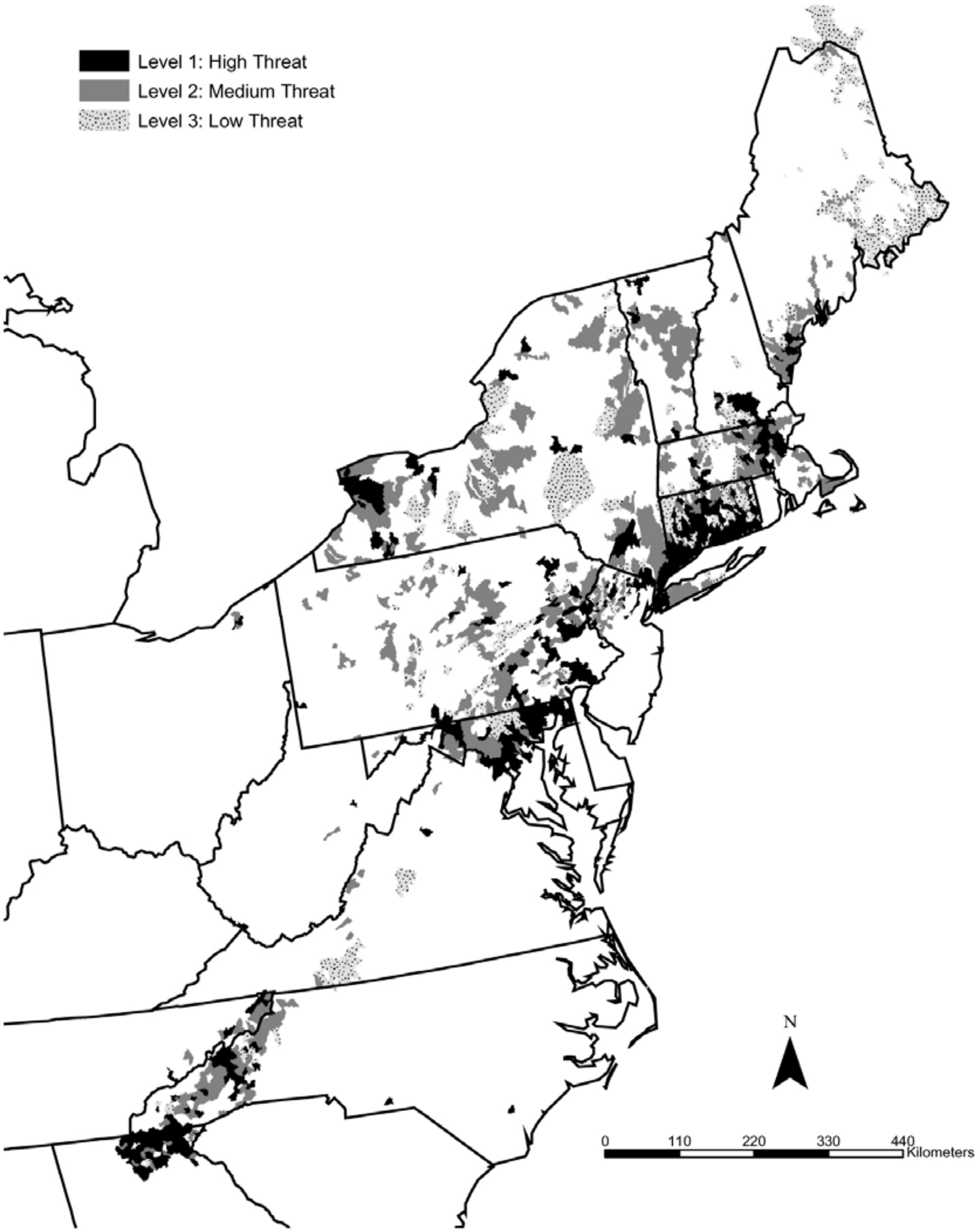
Appendix 2 Figure A2.14. Subwatersheds containing brook trout in North Carolina, South Carolina, Tennessee and Georgia. Subwatersheds with Present: Intact and Present: Reduced (3 %) have retained at least 50 % the habitat maintaining self-sustaining populations of brook trout. Subwatersheds with a Present: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



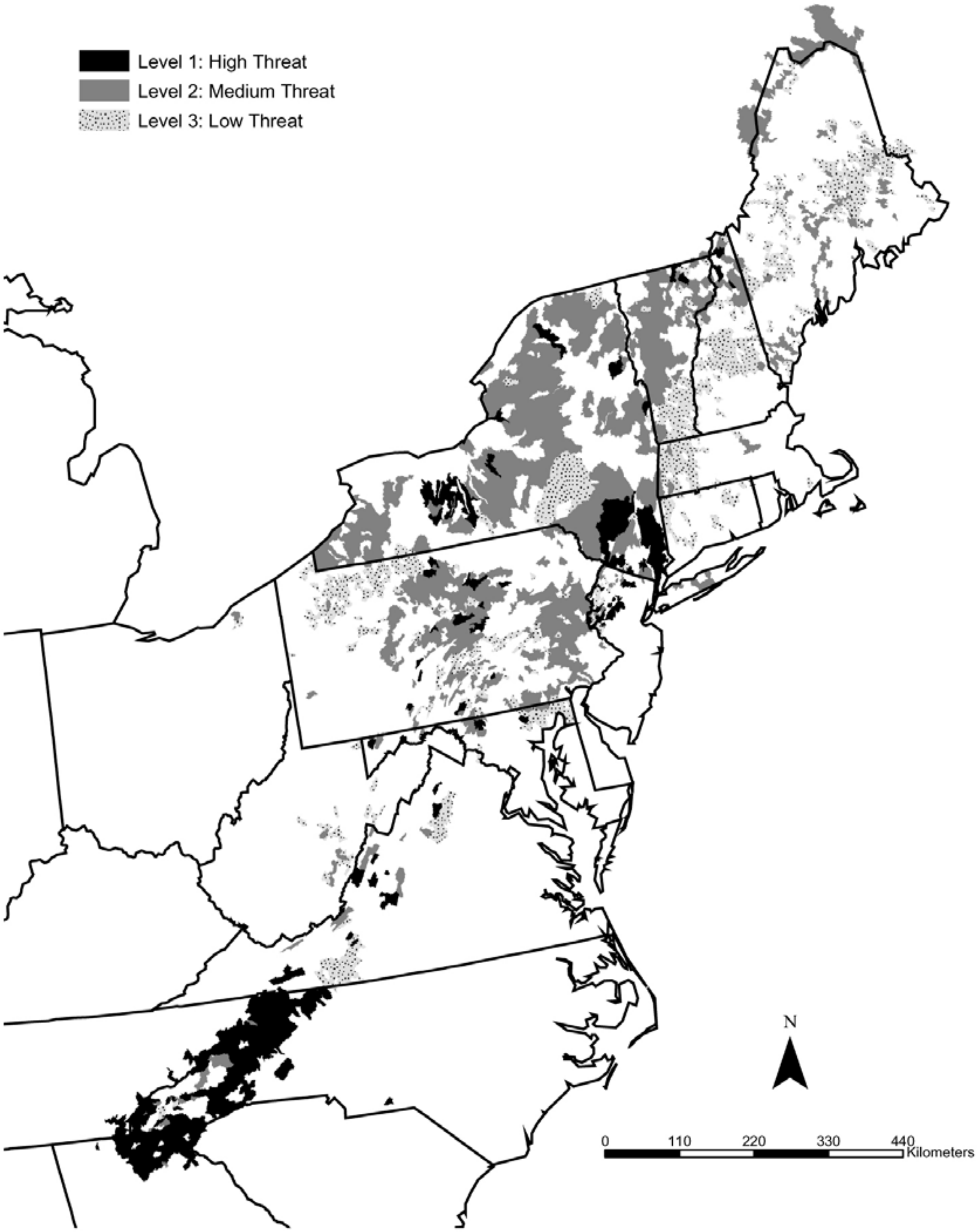
Appendix 3 Figure A3.1. Identified high water temperature (ranked as number 1) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (19.6%), Level 2 medium = reduction of life cycle component within subwatershed (14.9%) and Level 3 low = general concern, no documented loss or reduction of life cycle components (4.7%).



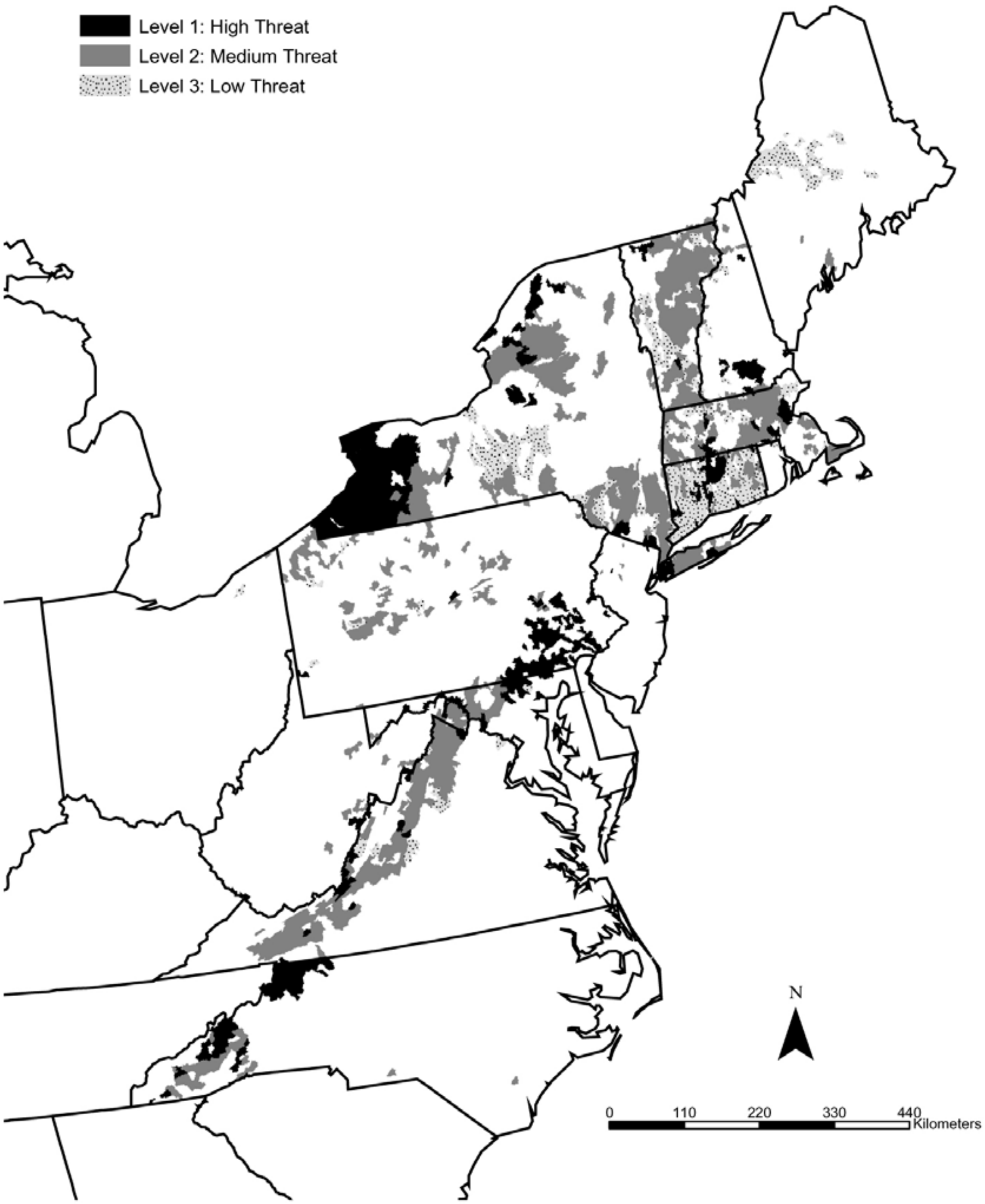
Appendix 3 Figure A3.2. Identified agriculture (ranked as number 2) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (15.3 %), Level 2 medium = reduction of life cycle component within subwatershed (20.4 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (7.7 %).



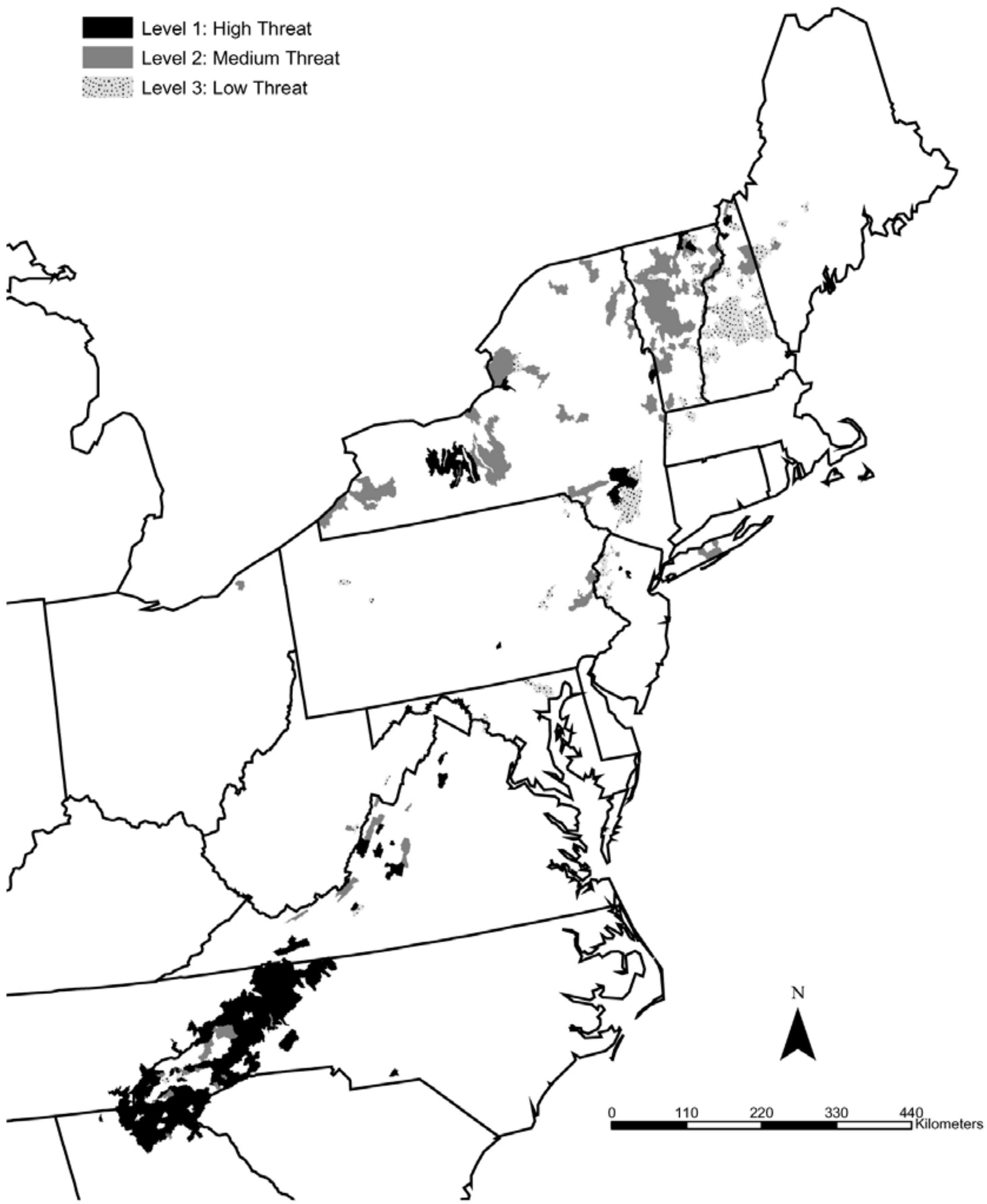
Appendix 3 Figure A3.3. Identified urbanization (ranked as number 3) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (9.7 %), Level 2 medium = reduction of life cycle component within subwatershed (15.3 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (7.8 %).



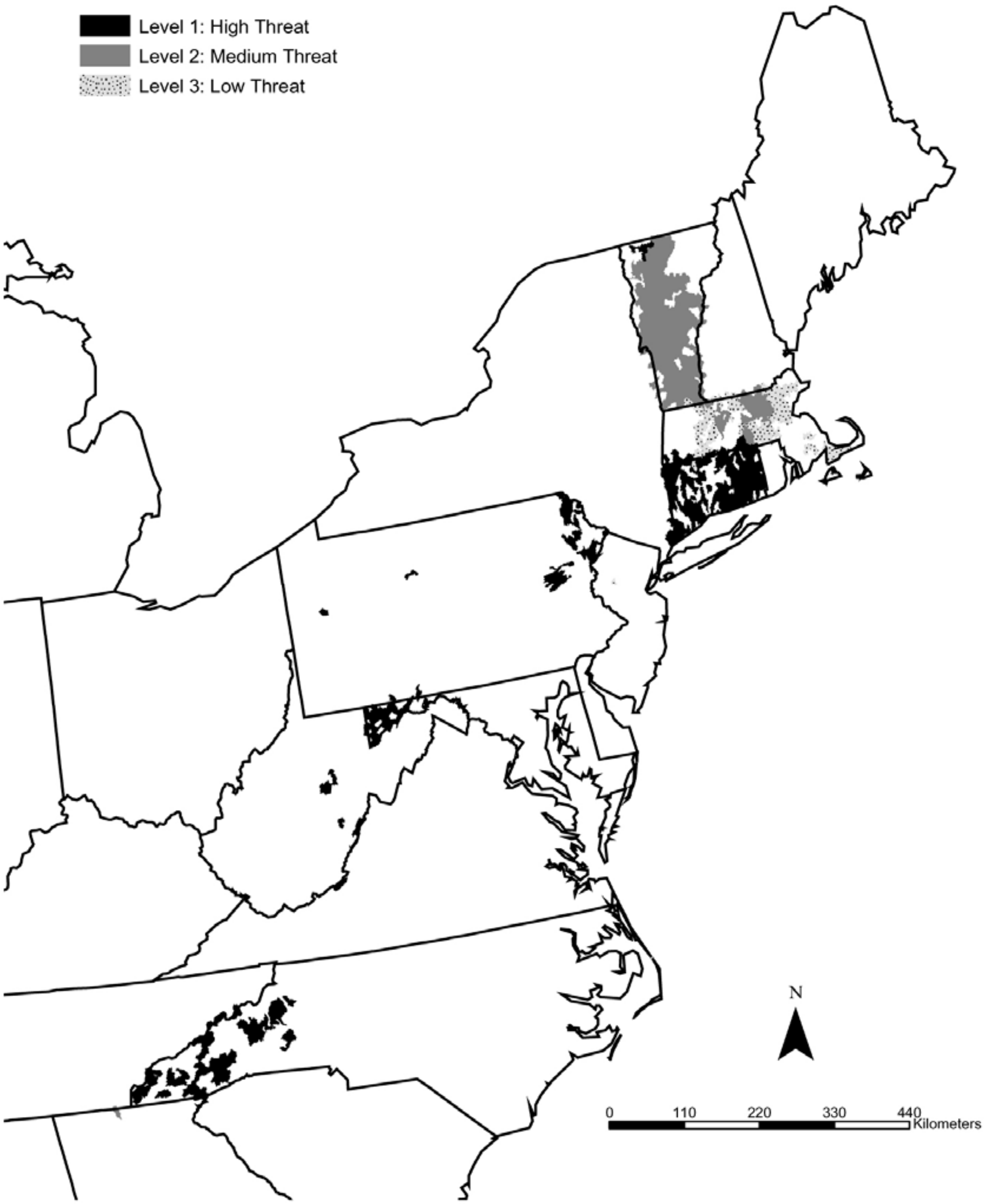
Appendix 3 Figure A3.4. Identified exotic fish (ranked as number 4) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (9.3 %), Level 2 medium = reduction of life cycle component within subwatershed (16.5 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (11.8%).



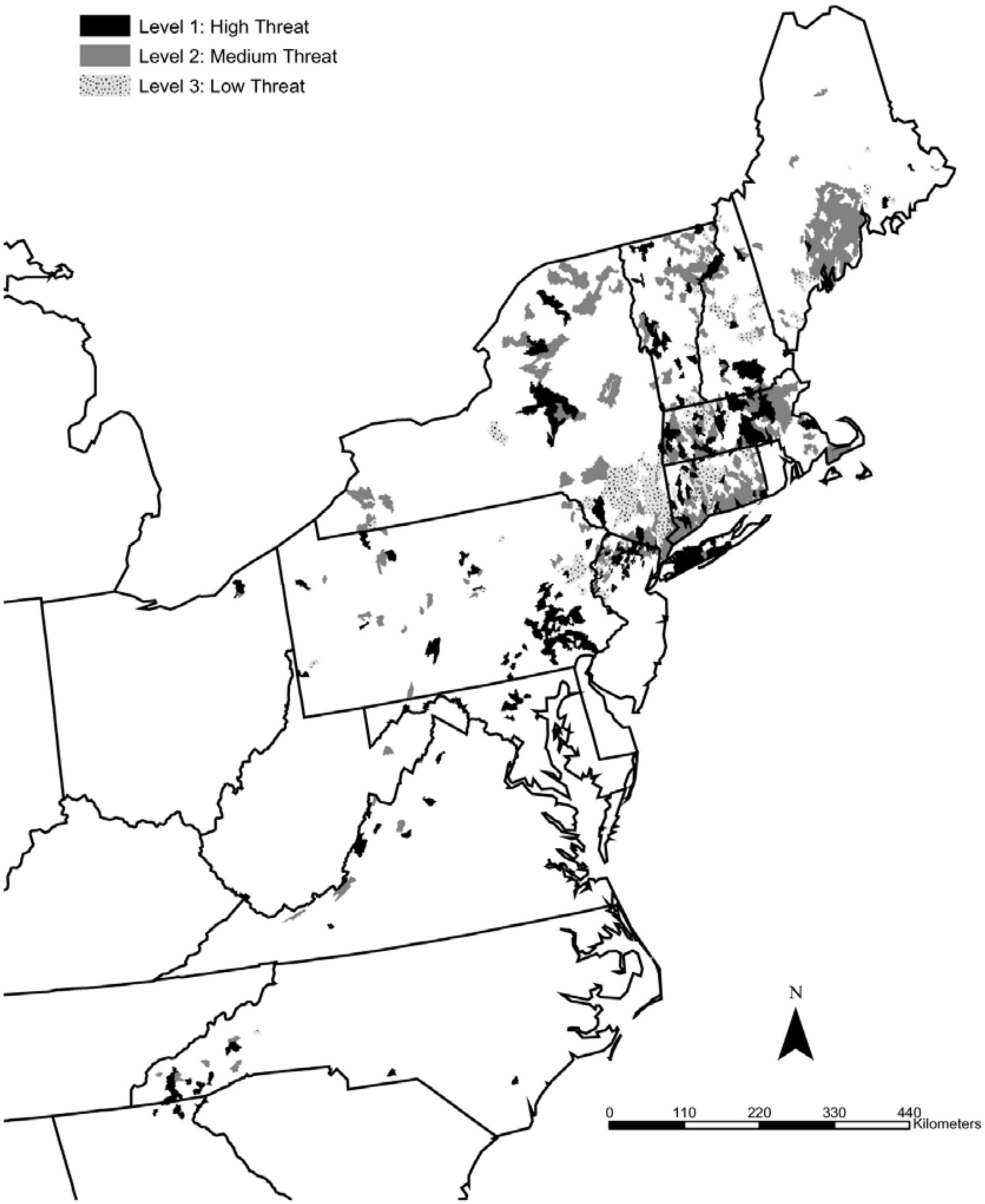
Appendix 3 Figure A3.5. Identified riparian (ranked as number 5) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (7.1 %), Level 2 medium = reduction of life cycle component within subwatershed (15.1 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (6.4 %).



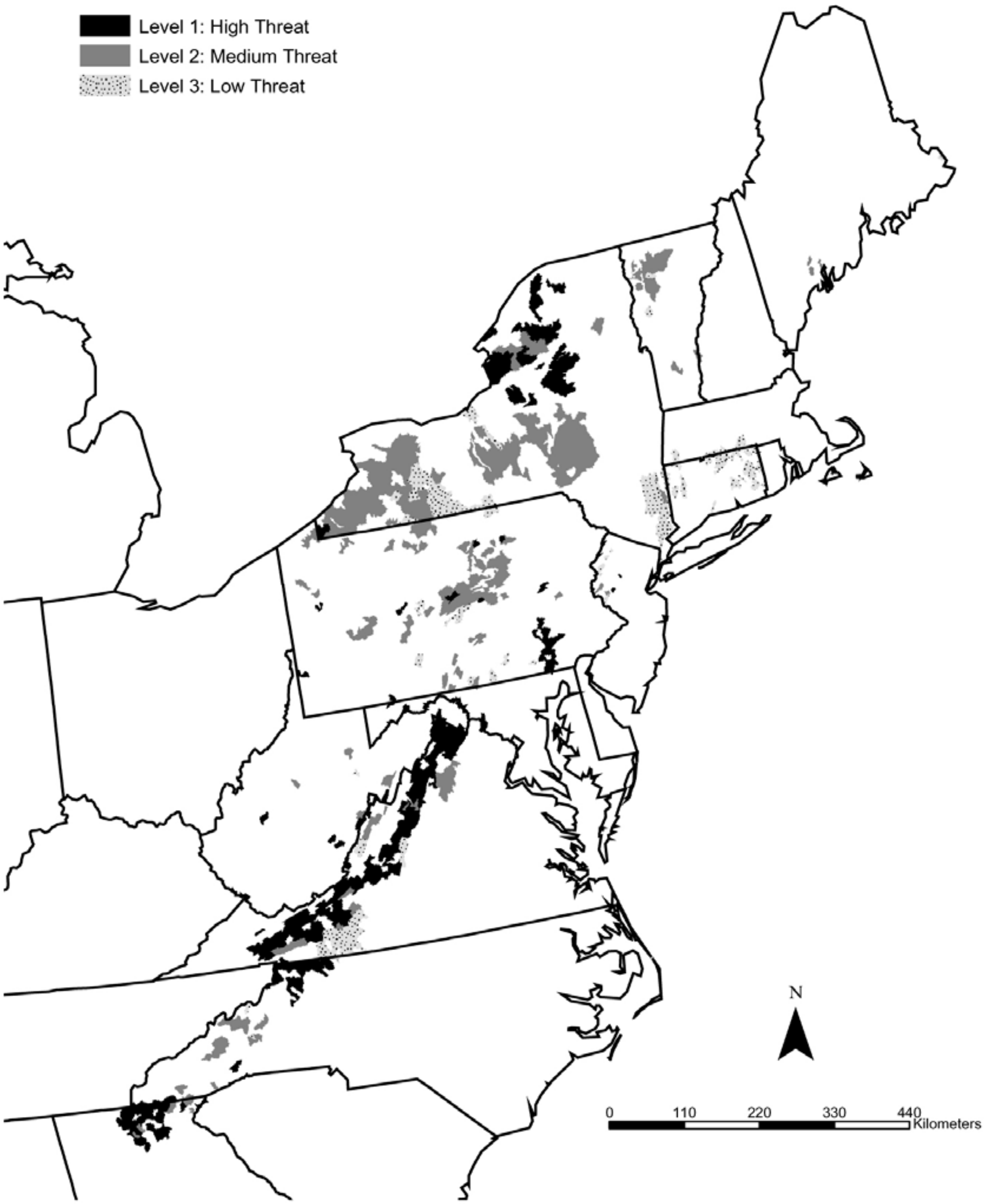
Appendix 3 Figure A3.6. Identified rainbow trout (ranked as number 6) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (6.8 %), Level 2 medium = reduction of life cycle component within subwatershed (4.0 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (3.0%).



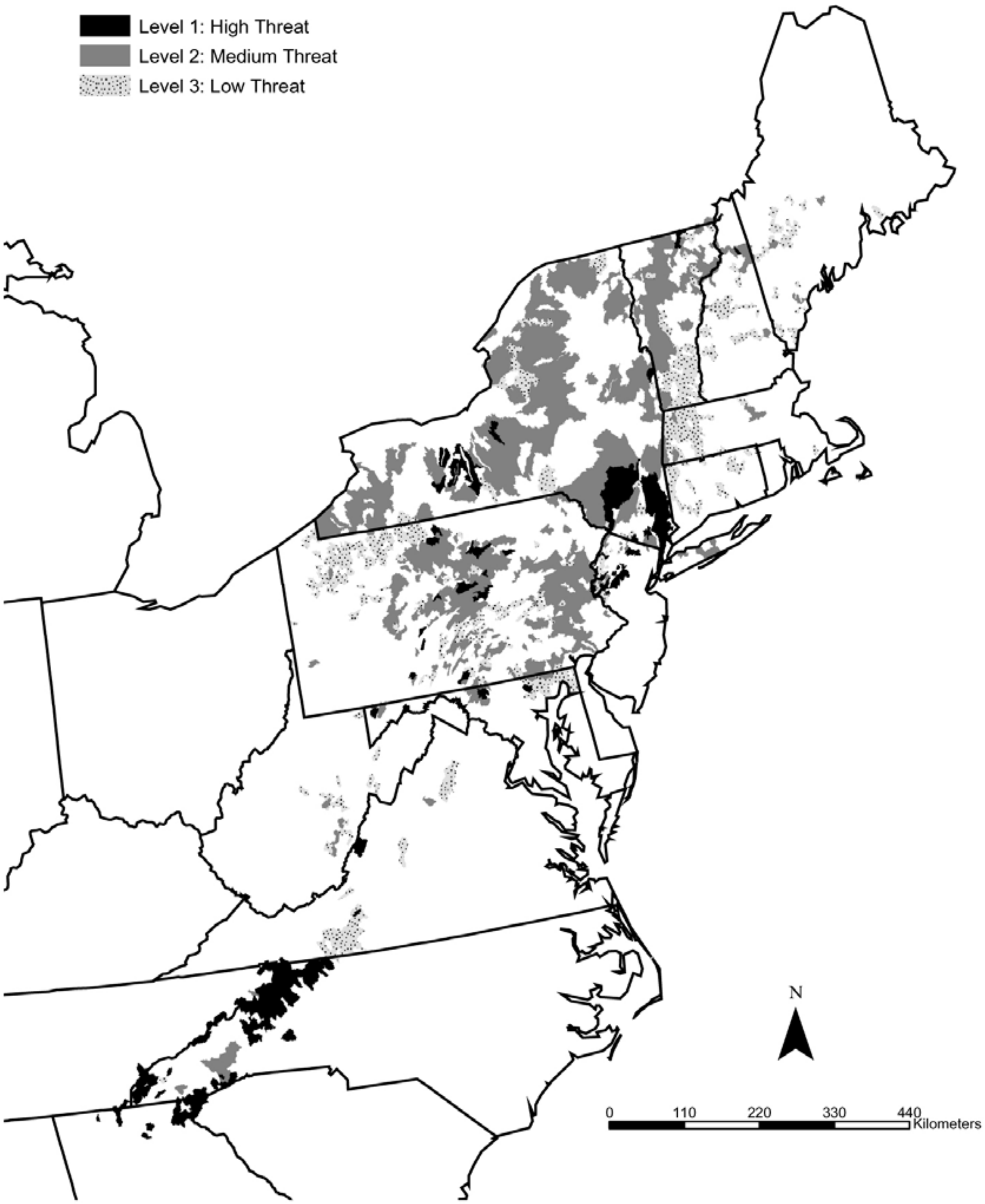
Appendix 3 Figure A3.7. Identified historic forestry (ranked as number 7) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (7.6 %), Level 2 medium = reduction of life cycle component within subwatershed (6.1 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (2.1%).



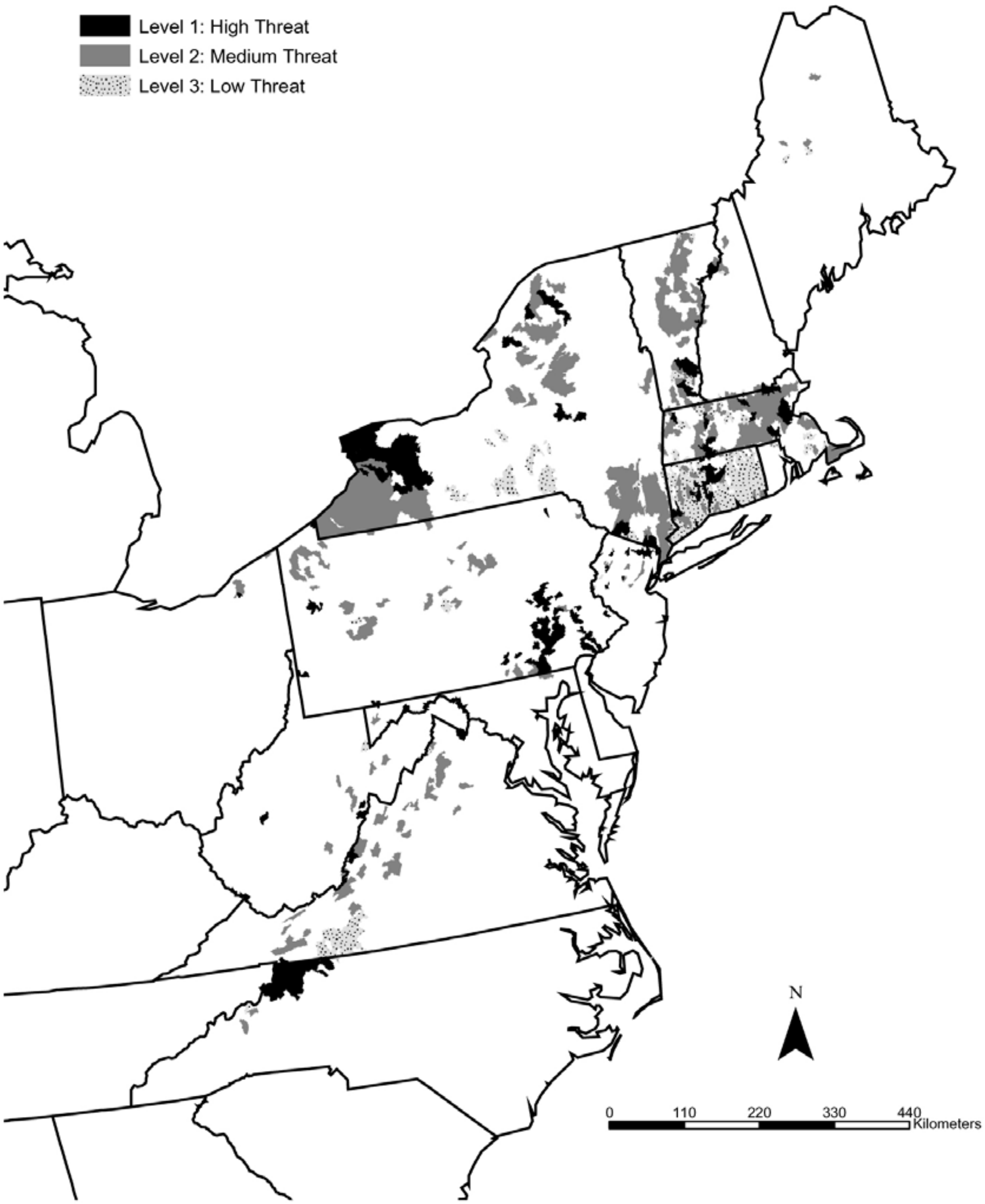
Appendix 3 Figure A3.8. Identified dam (ranked as number 8) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (6.7 %), Level 2 medium = reduction of life cycle component within subwatershed (8.7 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (3.3 %).



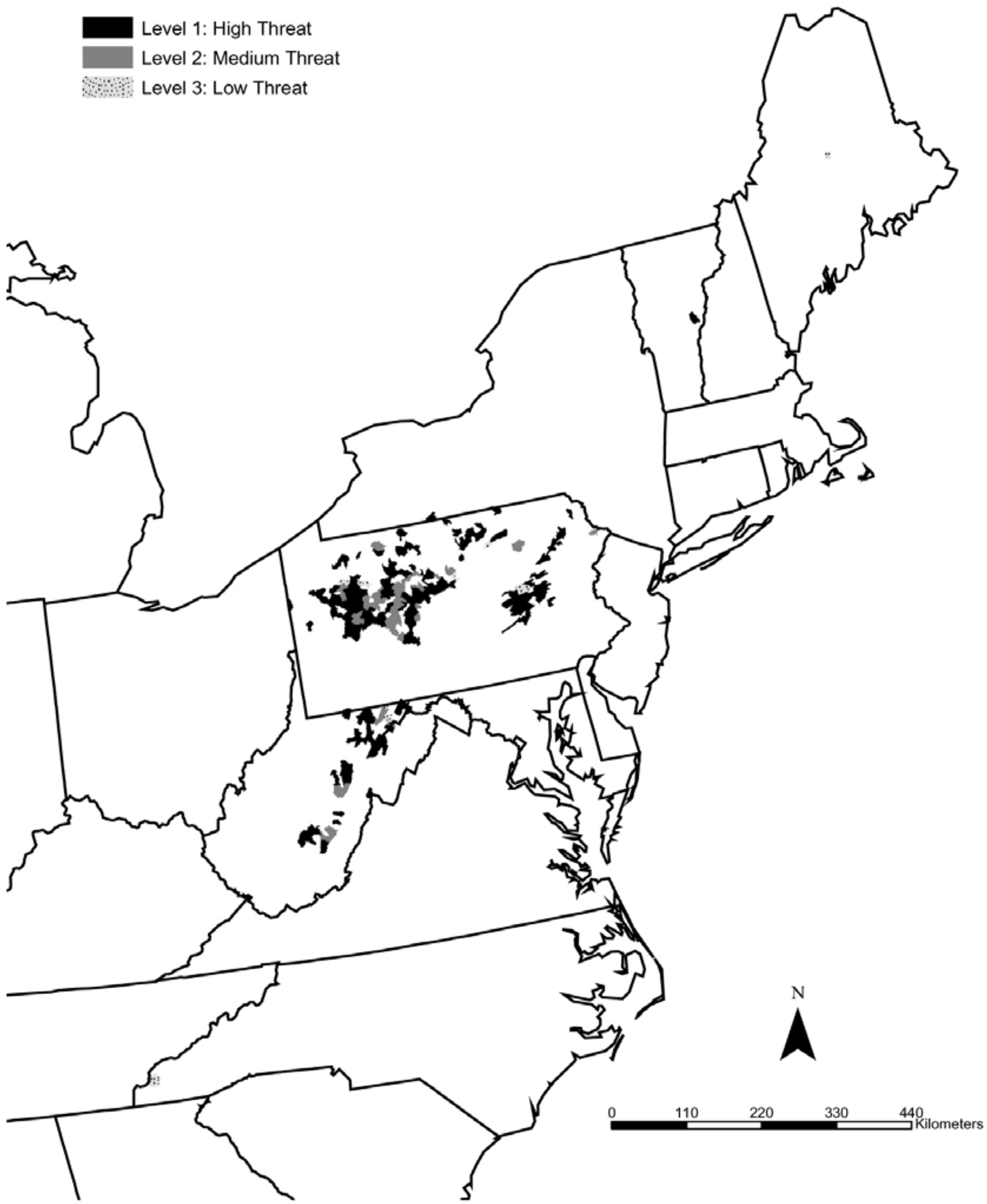
Appendix 3 Figure A3.9. Identified grazing (ranked as number 9) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (6.3 %), Level 2 medium = reduction of life cycle component within subwatershed (5.7 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (2.3 %).



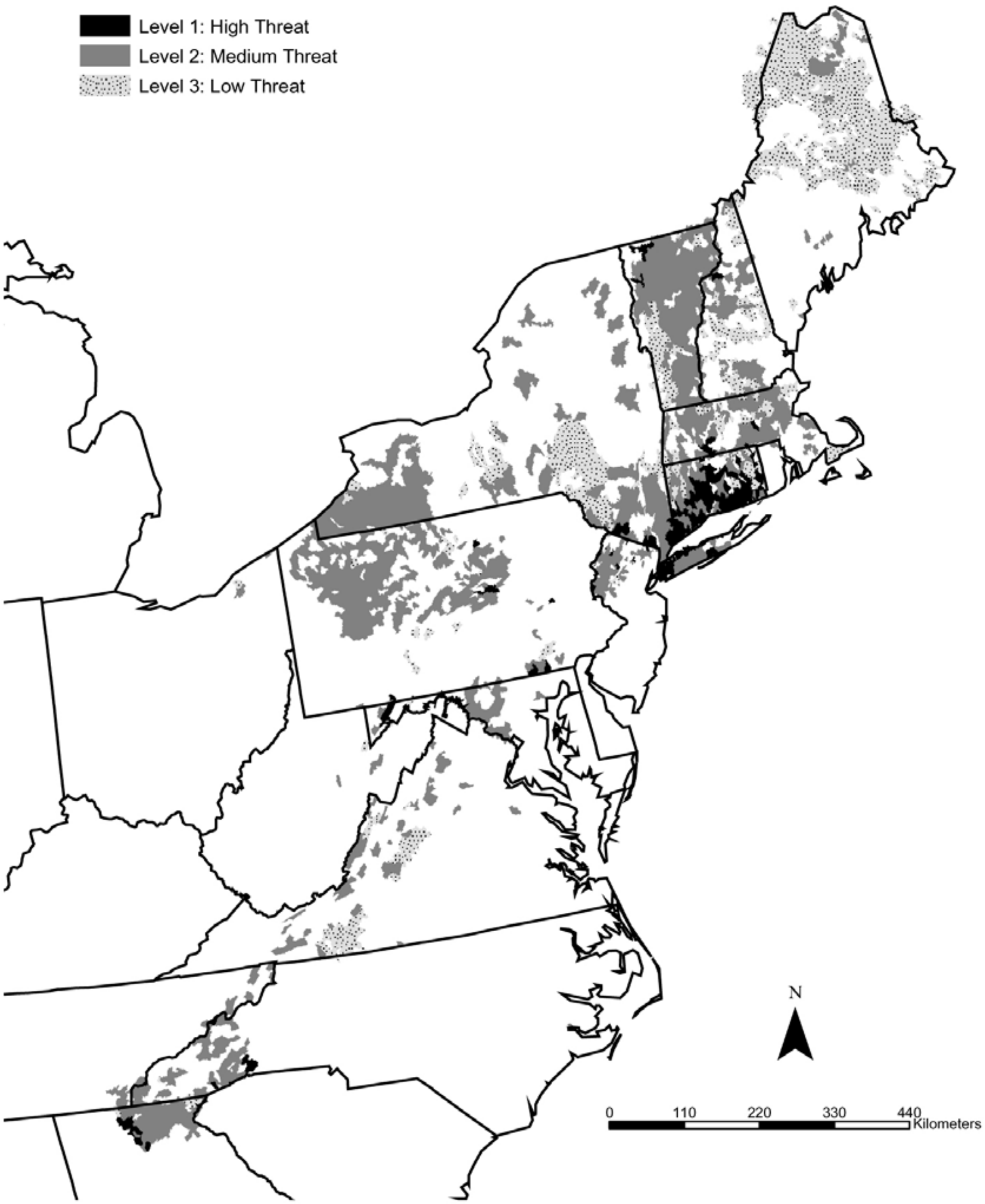
Appendix 3 Figure A3.10. Identified brown trout (ranked as number 10) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (5.2 %), Level 2 medium = reduction of life cycle component within subwatershed (13.7 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (8.0 %).



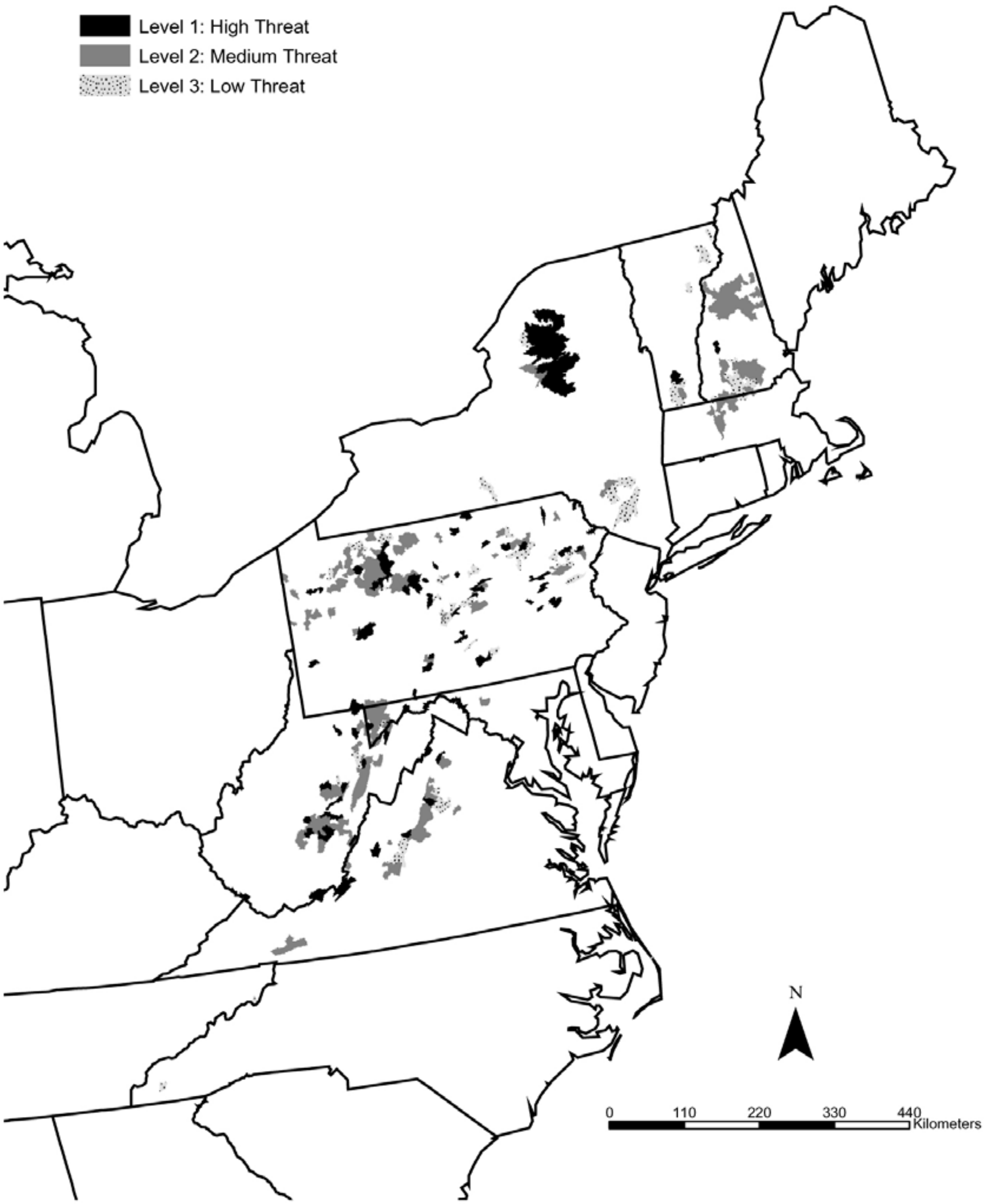
Appendix 3 Figure A3.11. Identified instream habitat (ranked as number 11) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (4.4 %), Level 2 medium = reduction of life cycle component within subwatershed (8.3 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (3.7 %).



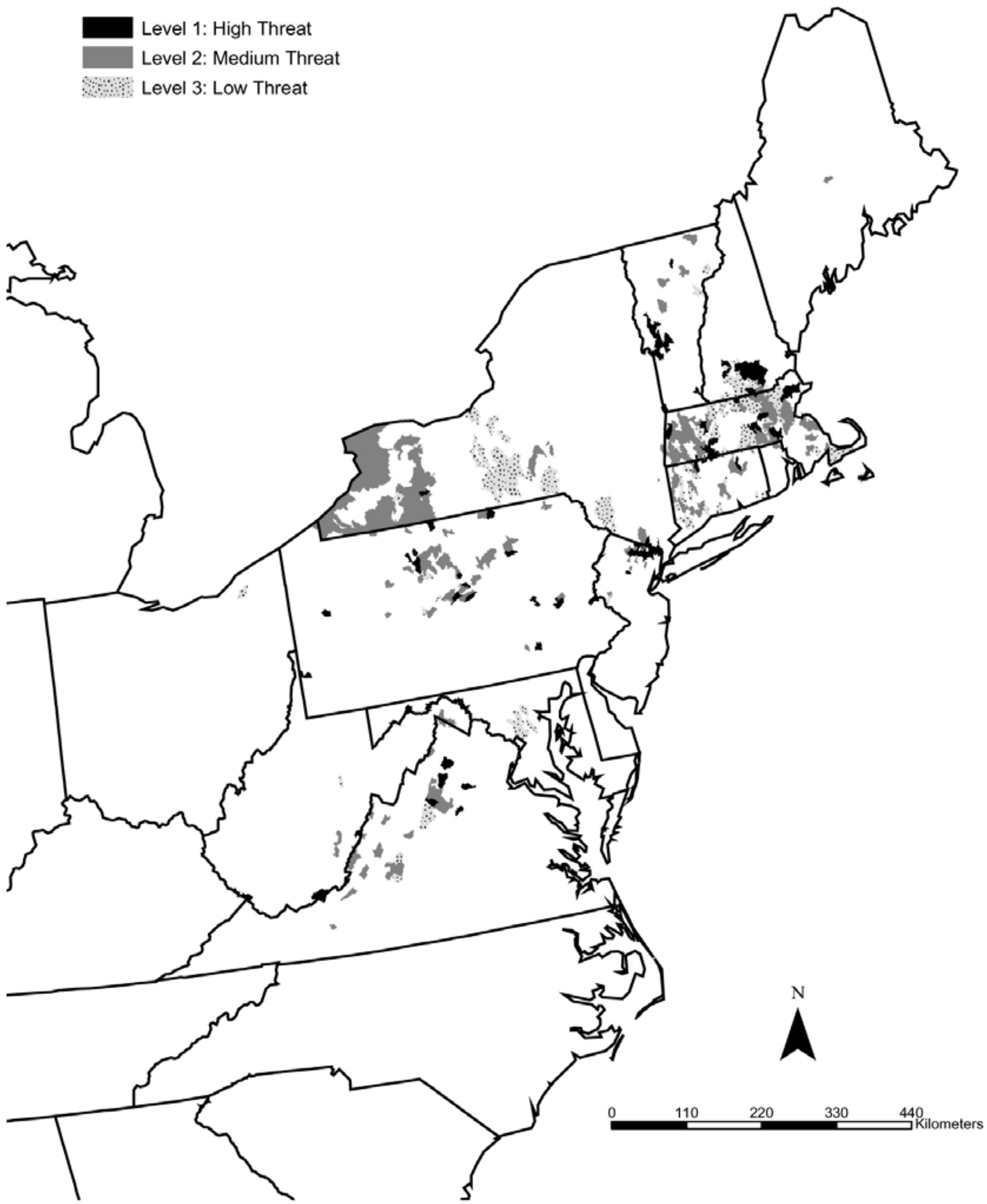
Appendix 3 Figure A3.12. Identified acid mine drainage (ranked as number 12) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (4.0 %), Level 2 medium = reduction of life cycle component within subwatershed (1.0 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (0.3 %).



Appendix 3 Figure A3.13. Identified road sediment (ranked as number 13) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (3.5 %), Level 2 medium = reduction of life cycle component within subwatershed (23.5 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (12.9 %).



Appendix 3 Figure A3.14. Identified acid rain (ranked as number 14) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (2.5 %), Level 2 medium = reduction of life cycle component within subwatershed (4.3 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (1.2 %).



Appendix 3 Figure A3.15. Identified minimum flow (ranked as number 15) perturbations to brook trout. Perturbations determined by expert opinion from 4,484 subwatersheds. Level 1 high = loss of life cycle component within subwatershed (2.0 %), Level 2 medium = reduction of life cycle component within subwatershed (4.6 %) and Level 3 low = general concern, no documented loss or reduction of life cycle components (2.3%).

Appendix 3 Table 1. State summary of Level 1 high perturbations to brook trout in streams.

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical	Threat Categories 1,2,3																	
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	20	7	20		0	5	**311**
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	8	1	31		0	0	**205**
Riparian habitat	0	1	5	14		89	28	1	74	0	14	21	10	67		0	0	**324**
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	167	84	40		1	65	**705**
Urbanization	8	0	8	28		42	100	54	69	2	7	12	69	42		5	0	**446**
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	163	2	27		0	44	**300**
Mining	0	0	1	1		0	0	2	39	0	22	3	1	10		0	0	**79**
Chemical																		
Low pH -Acid rain	0	1	2	0		20	0	0	55	0	18	30	1	0		3	0	**130**
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	187	93	0		13	0	**910**
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	6	2	0		0	0	**88**
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	8	0	0		0	0	**13**
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	0	2	1		0	0	**3**
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	44	4	143		38	86	**437**
	ME	**NH**	**VT**	**MA**	**RI**	**NY**	**CT**	**NJ**	**PA**	**OH**	**WV**	**VA**	**MD**	**NC**	**SC**	**TN**	**GA**	**TOT**
Exotics coldwater																		
Rainbow trout	0	2	4	0		12	0	4	1	0	0	43	0	138		37	86	**327**
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**
Exotics cool/warm water																		
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**	**0**	**754**	**599**	**391**	**1051**	**10**	**205**	**752**	**372**	**711**	**0**	**108**	**339**	**5659**

Appendix 3 Table 2. State summary of Level 1 and Level 2 perturbations to brook trout in streams.

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical	Threat Categories 1+2																	
Minimum flow	1	0	18	69		64	14	40	54	0	7	45	0	0		0	0	**312**
Surface water withdrawals	3	0	6	36		4	17	1	7	0	0	2	53	0		0	0	**129**
Ground water withdrawals	1	0	0	58		7	1	10	13	0	0	0	75	0		0	0	**165**
Floods	3	26	0	3		30	0	0	18	1	0	4	4	0		0	0	**89**
Debris flows	0	0	0	0		4	0	0	0	0	0	8	0	0		0	0	**12**
Dams (inundation)	105	17	60	106		71	85	100	89	3	1	28	7	28		0	5	**705**
Stream fragmentation (roads)	73	2	94	100		141	0	95	33	3	0	198	8	9		9	2	**767**
In stream/lake habitat	3	5	68	91		138	34	32	100	4	12	80	2	33		0	0	**602**
Riparian habitat	3	4	129	93		190	46	7	165	1	37	209	42	103		0	0	**1029**
Historic Sediment - roads			106			0	0	0	0	0	0	0	0	0		0	1	**107**
Sediment – roads	27	35	170	96		130	122	114	248	3	9	66	42	67		17	79	**1225**
Non-road sediment																		
Historic agriculture	3	0	34	24		39	0	0	10	0	0	1	40	0		0	13	**164**
Agriculture	86	4	121	15		211	39	52	532	0	104	214	91	87		17	74	**1647**
Urbanization	58	2	65	80		126	122	111	233	4	21	26	100	101		16	76	**1141**
Historic forestry	0	0	163	24		31	139	0	39	1	9	34	28	82		0	83	**633**
Forestry	82	16	40	0		124	0	3	195	0	96	4	2	69		6	5	**642**
Recreation	10	11	4	0		17	0	12	5	1	1	0	0	12		0	11	**84**
Historic grazing	0	0	10	0		14	0	0	4	0	0	1	0	0		0	4	**33**
Grazing	3	0	19	0		117	0	8	111	0	13	205	2	49		0	52	**579**
Mining	10	0	1	1		13	0	6	185	0	30	4	1	12		0	0	**263**
Chemical																		
Low pH –Acid rain	0	38	3	10		22	0	0	123	0	53	65	23	0		0	0	**337**
Low pH –Acid mine drainage	0	0	1	0		0	0	0	172	0	43	0	11	0		0	0	**227**
Dissolved oxygen	6	0	6	1		2	0	0	9	0	1	0	1	0		0	0	**26**
Water temperature – high	48	8	116	85		274	165	96	463	4	6	253	106	0		5	0	**1629**
Water temperature – low	0	1	0	5		3	0	2	0	0	0	0	1	0		0	0	**12**
Eutrophication	6	1	7	5		39	18	27	31	0	0	148	31	0		0	0	**313**
Gas super saturation	0	0	0	0		0	0	0	0	0	0	1	0	0		0	0	**1**
Turbidity	1	0	6	0		6	0	0	7	0	6	188	24	0		0	0	**238**
Heavy metals	1	3	0	0		3	0	0	22	0	0	0	5	0		0	0	**34**
Pesticides	3	0	0	0		2	0	0	1	0	0	130	5	1		0	0	**142**
Historic pesticides	0		0	0		3	0	0	0	0	0	0	0	0		0	0	**3**
Biological																		

All exotics	65	30	106	9		241	0	65	298	1	4	64	17	164		38	87	**1189**
	ME	**NH**	**VT**	**MA**	**RI**	**NY**	**CT**	**NJ**	**PA**	**OH**	**WV**	**VA**	**MD**	**NC**	**SC**	**TN**	**GA**	**TOT**
Exotics coldwater																		
Rainbow trout	1	16	76	0		57	0	7	9	1	1	62	0	163		37	87	**517**
Brown trout	4	16	88	9		218	0	64	296	0	3	6	15	99		9	26	**853**
Lake trout	1	1	0	0		0	0	0	1	0	0	0	0	0		0	0	**3**
Landlocked salmon	1	4	1	0		0	0	0	0	0	0	0	0	0		0	0	**6**
Other________	5	1	0	0		6	0	0	0	0	0	0	0	0		0	0	**12**
Exotics cool/warm water																		
Smallmouth bass	38	9	7	1		47	0	0	0	0	0	0	3	1		0	0	**106**
Largemouth bass	16	7	1	0		11	0	0	0	0	0	0	0	0		0	0	**35**
Walleye	0	0	1	0		12	0	0	0	0	0	0	0	0		0	0	**13**
Northern pike	5	4	2	0		12	0	0	0	0	0	0	0	0		0	0	**23**
Other_________	31	4	2	0		4	0	0	3	0	0	0	0	0		0	0	**44**
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	12	0	0		0	0	**12**
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	2	5		0	0	**7**
Diseases	0	0	0	0		1	0	0	0	0	0	0	0	0		0	0	**1**
Beavers	117	0	0	27		197	0	8	4	0	0	6	4	0		0	0	**363**
Bird predation	1	0	0	0		53	0	0	0	0	0	0	0	0		0	0	**54**
Historic overfishing	0		0	0		3	1	0	0	0	0	0	0	0		0	0	**4**
Historic mining												0					1	**1**
Total	**821**	**265**	**1531**	**948**	**0**	**2687**	**803**	**860**	**3480**	**27**	**457**	**2065**	**745**	**1085**	**0**	**154**	**606**	**16534**

Appendix 3, Table 3. State summary of Level 1, Level 2 and Level 3 perturbations to brook trout in streams.

	ME	NH	VT	MA	RI	NY	CT	NJ	PA	OH	WV	VA	MD	NC	SC	TN	GA	TOT
Physical																		
Minimum flow	1	31	20	113		87	31	44	57	2	8	74	7	0		0	0	**475**
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	30	0	4		59	0	0	22	1	0	37	12	0		0	0	**168**
Debris flows	0	0	0	0		5	0	0	0	0	0	21	2	0		0	0	**28**
Dams (inundation)	114	57	66	123		95	118	124	104	3	1	28	7	29		0	5	**874**
Stream fragmentation-roads	73	66	136	114		173	85	104	41	4	0	312	8	9		9	2	**1136**
In stream/lake habitat	5	6	73	105		156	150	34	104	4	13	133	2	34		0	0	**819**
Riparian habitat	61	26	163	118		216	170	7	171	2	37	259	43	103		0	0	**1376**
Historic Sediment - roads	0	0	106	0		0	0	0	0	0	0	1	0	0			1	**108**
Sediment – roads	395	108	203	121		169	161	125	263	4	10	177	45	68		17	79	**1945**
Non-road sediment																		
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	282	91	93		17	74	**2058**
Urbanization	194	34	66	98		176	172	138	276	4	21	61	115	113		16	76	**1560**
Historic forestry	0	0	163	94		34	139	1	39	0	9	39	28	82		0	83	**711**
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	264	2	51		0	52	**736**
Mining	11	1	1	1		29	0	7	186	0	30	9	1	13		0	0	**289**
Chemical																		
Low pH-Acid rain	0	69	13	12		27	0	0	154	0	56	76	24	1		1	0	**433**
Low pH-Acid mine drainage	1	0	1	0		0	0	0	178	0	43	0	14	3		0	0	**240**
Dissolved oxygen	8	31	6	1		3	10	0	13	1	1	0	1	0		0	0	**75**
Water temperature – high	124	41	140	99		304	170	120	494	4	6	292	108	0		9	0	**1911**
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	148	31	0		0	0	**401**
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	191	24	0		0	0	**273**
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	95	148	44		273	23	98	417	2	20	114	45	167		38	87	**1769**
	ME	**NH**	**VT**	**MA**	**RI**	**NY**	**CT**	**NJ**	**PA**	**OH**	**WV**	**VA**	**MD**	**NC**	**SC**	**TN**	**GA**	**TOT**
Exotics coldwater																		
Rainbow trout	7	73	89	3		64	0	32	18	1	3	71	6	165		37	87	**656**
Brown trout	25	44	129	43		237	23	92	414	0	18	49	43	100		9	26	**1252**
Lake trout	2	2	1	1		4	0	0	1	0	0	0	0	0		0	0	**11**
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	21	11	6		82	12	7	0	0	0	4	3	2		0	0	**286**
Largemouth bass	22	17	3	2		11	0	4	0	1	0	0	0	0		0	0	**60**
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	38	0	0		0	0	**44**
Poaching	0	0	0	0		0	0	0	0	0	0	10	0	0		0	0	**10**
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	32	4	0		0	0	**713**
Bird predation	2	0	0	0		56	0	0	0	0	0	0	0	0		0	0	**58**
Historic overfishing	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	860	1818	1490		3380	1714	1098	4024	44	511	2861	852	1130		159	606	**23136**

Appendix 3 Table 4. Perturbations to lakes and ponds in Maine , Vermont and New York.

	Category 1 Perturbations				Category 1+2 Perturbations				Category 1+2+3 Perturbations			
Perturbations:	**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**

	Category 1 Perturbations				Category 1+2 Perturbations				Category 1+2+3 Perturbations			
Perturbations:	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**	**ME**	**VT**	**NY**	**TOT**
Pesticides	0	0	0	**0**	1	0	0	**1**	8	0	0	**8**
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/warmwater												
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**