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Chapter

Rivers and Streams: Upgrading Monitoring of the Nation's Freshwater Resources - Meeting the Spirit of the Clean Water Act

Steven G. Paulsen, David V. Peck, Philip R. Kaufmann and Alan T. Herlihy

Abstract

The goal of the Clean Water Act (CWA) is to restore and maintain the chemical, physical and biological integrity of the waters in the United States. Much of the monitoring and assessment is reasonably delegated to the States to monitor and report the condition of their water to Congress through the Environmental Protection Agency. States have historically been fully occupied in monitoring the most egregious water quality problems along with select high priority water bodies. This approach, while addressing State priorities with finite resources, does not capture the full spectrum and scope of water quality conditions within and across State boundaries. Hence, the reporting on progress in meeting the goals of the CWA has not been realized. In this chapter, we describe the partnership between EPA, the States and Tribes to remedy this information gap for rivers and streams. Filling this gap requires both improved monitoring designs to reflect conditions across all waters as well as the expansion of indicators to move beyond water chemistry to include all three elements of the CWA goal—chemical, physical and biological integrity.

Keywords: streams, rivers, monitoring, assessment, National Rivers and Streams Assessment, United States, ecological indicators, survey design, National Aquatic Resource Assessments, water quality, biological integrity, physical habitat, Clean Water Act

1. Introduction

Access to credible, quantitative information regarding the status and trends in water resource conditions is essential for the development of effective national policies for managing water resources in the United States. The US Clean Water Act (CWA) expresses the national desire to restore and maintain the chemical, physical, and biological integrity of US waters and requires that information on status and trends be reported [1]. The need and desire to improve the quality of water resource assessments is not peculiar to the US. Australia has made assessment and management of its aquatic resources a major national focus [2–4]. The Water Framework Directive instituted by the European Community includes key components that are a general requirement for ecological protection and a general minimum chemical standard that is applicable to all surface waters [5]. An assessment of major river basins by 2007 was also called for in the Water Framework Directive [6]. Dwindling budgets for environmental protection, particularly for monitoring and assessment, suggest that all countries will face both technical and fiscal challenges of how to provide assessments that quantify water resource conditions over continental scales. Similar approaches to incorporating chemical, physical and biological information into assessments of individual (e.g., a single river reach) have been adopted by many countries. Much of the technical work in the US and elsewhere has focused on developing biological indicators (e.g., [7–11]). However, it remains unclear if improvements in the science of monitoring survey design have been adopted or implemented. In the US, randomized sampling designs are considered a critical element in support of regional and national surveys (e.g., [12, 13]) because the use of such designs provides a rigorous inference protocol for extending assessments of individual sites to the entire population of the water resource of interest.

The passage of the Clean Water Act (CWA) amendments to protect US water resources in 1972 [14] was an historic event resulting in a law that served as the gold standard for environmental protection globally. Two sections of the CWA stand out with respect to monitoring and assessment. Section 303(d) calls for States to develop a list of waterbodies that fail to support their designated use and to conduct a "Total Maximum Daily Load" (TMDL) analysis for these waterbodies…a total maximum daily load below which the offending "pollutant" should be kept in order to restore designated use. Under Section 305(b), States report to the US Environmental Protection Agency (EPA), which then reports to Congress and the public on the condition of the States' waters, the success or failure, if you will, of efforts to protect and restore waters. In spite of these reporting efforts, reviews of water quality monitoring programs in the US over the years have concluded that neither EPA nor any other U.S. federal agency was able to provide Congress and the public with an adequate assessment regarding the condition of US water bodies [1, 15–22]. These reviews pointed to a host of factors contributing to the problem. Chief among them were the lack of standardization in monitoring approaches, designs, field and laboratory protocols, and indicators used for assessments. To bridge this information gap, the EPA, States, and Tribes, began collaborating on a monitoring effort to produce assessments that provide the public with improved water-quality information at the national and regional scales - the National Aquatic Resource Surveys (NARS). The NARS includes surveys and assessments describing four major water resource types: estuaries, lakes and reservoirs, wetlands, and rivers and streams. This chapter describes one component of the NARS, the National Rivers and Streams Assessment (NRSA), discussing the origins, evolution and initial results.

The NRSA began as a concept in 2002. The EPA Office of Water (OW) wanted to produce a national assessment for one waterbody type. The funds were insufficient to conduct a full national survey. EPA's Office of Research and Development (ORD) had been partnering with the EPA Regional Offices and States in the western half of the US to evaluate approaches to monitoring and assessing rivers and streams across broad geographic scales [23]. A decision was made to use the data collected on wadeable streams in the western pilot study and combine them with a new effort to collect data on wadeable streams in the eastern half of the country using the same survey design, field and laboratory methods, and assessment approach. This collaboration resulted in the Wadeable Streams Assessment (WSA), the first nationally consistent, statistically rigorous study of US wadeable streams [24, 25]. The EPA and its State partners published the approach and findings of the WSA in a special issue of the Journal of the North American Benthological Society (JNABS, 2008, Issue 27 now named Freshwater Science). Following the WSA, the EPA and the State partners expanded beyond "wadeable streams" to include all flowing waters in the National Rivers and Streams Assessments (NRSA). The first NRSA survey was conducted in 2008–2009 and has repeated every 5 years thereafter (2013–2014 and 2018–2019 at the time of this writing). This chapter uses the results from the 2013–2014 NRSA survey. We describe insights into the conceptual approach and methods used to make NRSA the only monitoring effort to fulfill the original promise of the CWA for reporting on our success or failure in restoring and maintaining the physical, chemical and biological integrity of the nation's rivers and streams.

2. Methods

2.1 Study area

The focus of NRSA 2013–2014 survey is perennial rivers and streams of the 48 conterminous states. While Alaska and Hawaii are not included in NRSA yet, pilot studies have been conducted in both States and will, hopefully, lead to inclusion of these two states in future assessments [26]. This area covers 7,788,958 km^2 and includes rivers and streams running through private, state, tribal, and federal land.

2.2 Survey design

Sampling locations were selected for the NRSA with a state-of-the-art sample survey design approach [12, 26]. Statistically designed sample surveys have been used in a variety of fields (e.g., election polls, forest inventory analysis, national wetlands inventory) to determine the status of resources of interest (e.g., voter preferences, timber availability, and wetland acreage). Sample surveys have been a tool of choice in a variety of fields when it's essential to be able to make unbiased estimates of the characteristics of a large population by sampling a representative set of a relatively small percentage of sites. Because randomization is incorporated into the sample site selection, the estimates are accompanied by robust estimates of the uncertainty. This approach is especially cost-effective when the population is so large that not all components can be sampled. The target population for the NRSA was the perennial rivers and streams in the conterminous US. To identify the location of all perennial streams, the NRSA design team used the National Hydrography Dataset (NHD-Plus; [27]), a comprehensive set of digital spatial data on surface waters at the 1:100,000 scale For 2008–2009, the NRSA findings represent roughly 1.2 million miles or 1.9 million kilometers of perennial rivers and streams [28].

For each NRSA survey, approximately 1800 sites to be sampled are allocated based on the density of river and stream length across the aggregated ecoregions and States (**Figure 1**), and 10 EPA regions [29]. The intent of the design is to provide more sampling in areas of high river and stream length and less sampling in areas with less length of flowing water. The entire design process (i.e., site selection and weighting during analyses) enables unbiased assessment results (including estimates of uncertainty) that are representative of the condition of the streams and rivers throughout the region and the nation.

For the NRSA, results are reported at three scales: national, three major landform and climatic reporting regions (**Figure 2A**), and nine ecological regions (aggregations of Omernik Level III ecoregions; **Figure 2B**). While not frequently used for reporting in the periodic assessments, the NRSA has sufficient sample sizes to assess condition in each of the 10 EPA regions [29] and in at least 12 of the 18 major hydrologic basins across the conterminous US. For this chapter, results

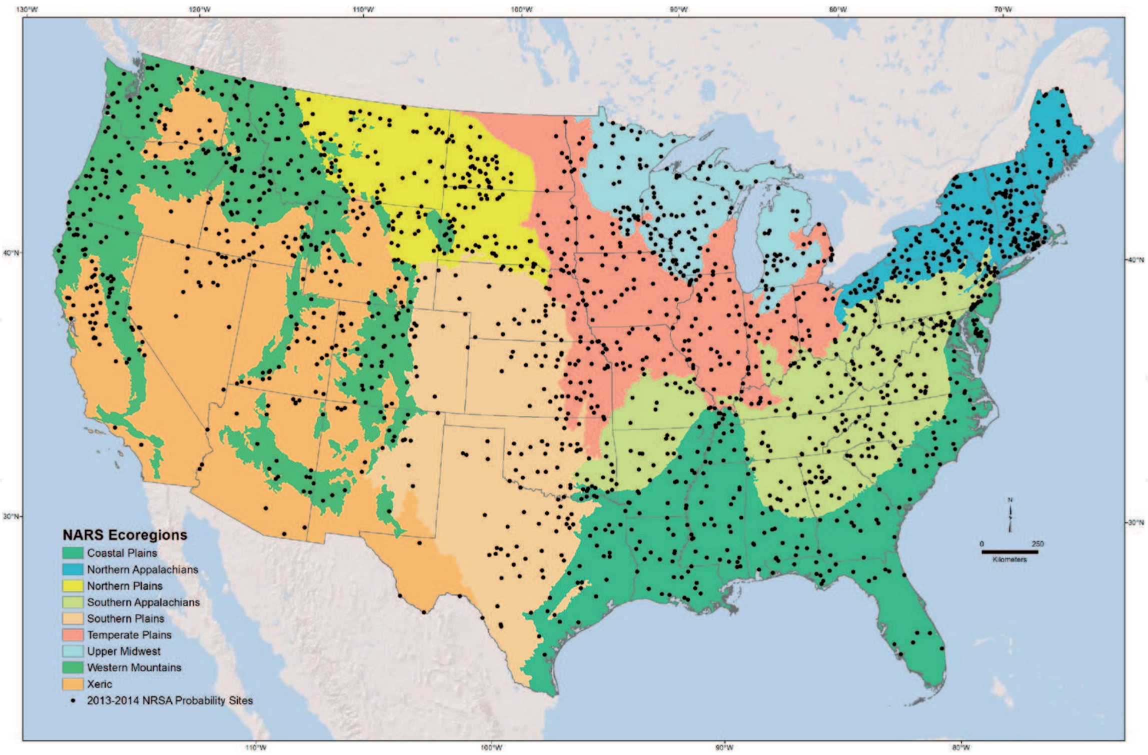

Figure 1.
Locations of the 1853 randomly selected sites sampled in the 2013–2014 National Rivers and Streams Assessment. NARS = National Aquatic Resource Surveys.

for the conterminous U.S. and the three climatic regions are presented as examples of assessment outputs that the NRSA produces. For more detailed results at finer spatial scales see [30].

2.3 Field sampling

Each site is sampled by a 2- to 4-person field crew during a low-flow index period (typically summer) [31]. More than 80 trained crews sampled 1853 random stream and river sites with standardized field protocols over the course of the 2013–2014 field seasons. The field protocols are designed to produce comparable data regarding the ecological condition of stream and river resources and the key stressors at all sites [32, 33].

During each site visit, crews use standardized field procedures to lay out the sample reach and systematically spaced transects to guide data collection [32]. For stream and river sites that require a boat, crews follow a conceptually similar process but are limited to one pass sampling in a downstream direction [33]. Crews record site data and instream and riparian physical habitat measurements on standardized field forms or electronic field recorders for each site. In addition to comprehensive pre-field season training, the proficiency of each crew is evaluated early in the field season, and 10% of the sites are revisited as part of the quality assurance plan for the survey [34].

Field crews collect information in two categories. The first category includes samples that require shipping to a laboratory for additional processing. This includes water samples for chemical and "chemical-like" data (e.g., algal pigments), and for biological samples (i.e., fish, benthic macroinvertebrates and periphyton). The second category includes data that are recorded in the field on standardized electronic forms. The physical habitat data originate as measurements and observations made in the field. These are then forwarded to staff scientists that process the data into metrics and indicators.

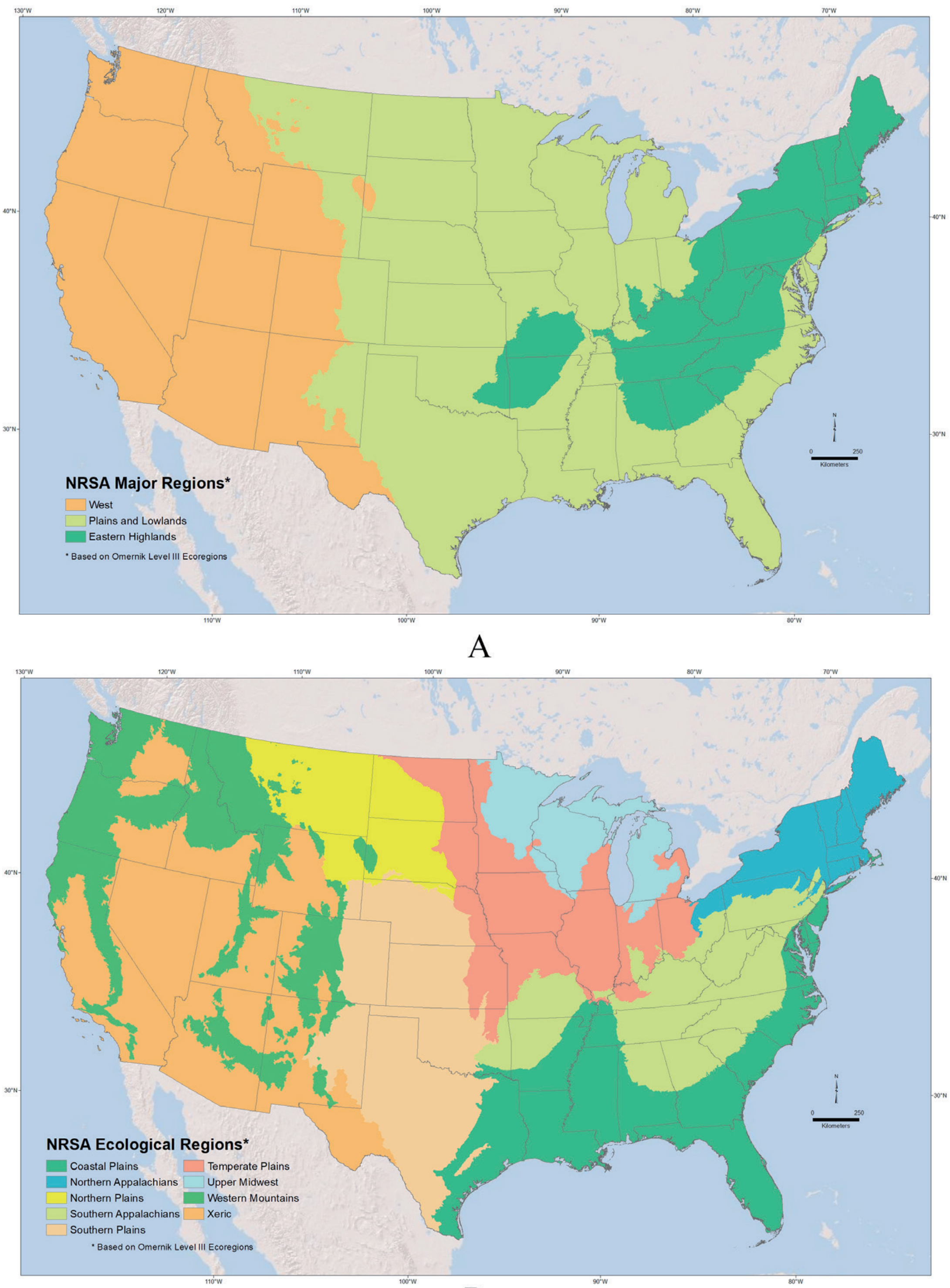

Figure 2.
(A) Three major landforms and climate reporting regions in the National Rivers and Streams Assessment (NRSA). (B) Nine aggregated ecoregions used for reporting in NRSA.

Fish and benthic macroinvertebrate samples, collected from each stream and river reach, are sent to taxonomists for identification [35, 36]. Water samples for chemical analyses are collected at mid-stream or river reach. Measurements of physical habitat attributes are collected at systematically spaced locations along the entire reach sampled. The chemical and physical habitat data are translated into descriptors of chemical or physical habitat or indicators of anthropogenic disturbance (i.e., stressors) that might impact biological condition.

The historic concerns about the lack of consistency and comparability in monitoring programs are resolved in the NRSA through the use of standardized field and laboratory protocols [32, 37]. Standardization allows the data to be combined to produce a nationally consistent assessment. Standardization also allows comparison to other methods. The 2004 survey provided an opportunity to examine the comparability of different sampling protocols by applying both the NRSA method and various state or USGS methods to a subset of the sites (e.g., [38, 39]).

The NRSA transforms the collected data into "indicators" that are meaningful to the public or can be translated into meaningful statements for the public. For example, over 3000 measurements of physical habitat structure are collected from each sample site and ultimately compacted into four indicators that can be meaningful to the public. Similarly, at each site the benthic macroinvertebrate and fish samples collected are reduced to a list of species present and their relative abundance. This information is then transformed into three indices of biotic integrity, one for the fish and two for the macroinvertebrates.

2.4 Setting expectations: reference conditions

Setting reasonable expectations for each indicator is among the greatest challenges in assessing ecological condition [40, 41]. For the NRSA, ecological condition assessments based on chemical, physical, and biological field measurements at each site were compared to a benchmark of what one would expect to find in relatively undisturbed streams and rivers within that region [42]. Sets of least disturbed reference sites within each region were used to: (1) develop and calibrate multimetric indices (MMIs) and observed/expected (O/E) indices, and (2) set thresholds for three condition classes: good, fair, and poor [42]. Conditions at these sets of relatively undisturbed stream and river sites are called "reference conditions".

Rather than relying solely on best professional judgment to set these reference condition benchmarks or even to finalize the sites considered least disturbed/reference, the NRSA data analysts first generated a pool of candidate sites that might potentially serve as least disturbed reference. Candidate sites for this reference pool came from either hand-selected sites recommended by State and EPA Regional participants or were screened as a subset from the pool of sites selected using the probability design site selection process. The only requirement was that site-specific data be available. This reliance on data for the final determination of reference sites rather than solely relying on best professional judgment as recommended in the application of Tiered Aquatic Life Use (TALU) framework and the biological condition gradient [43] is one of the hallmarks of NARS – the use of data-driven determinations where possible.

The pool of candidate reference sites was filtered through a set of physical and chemical data screens (i.e., riparian condition, nutrients, chloride, turbidity, excess fine sediments). When a site passed through all the data screens it was used to describe the distribution of condition indicators among least disturbed sites in that region (i.e., regional reference condition) "Pristine" landcover in watersheds was not required for a site to be considered "reference"; for example, sites in human-use dominated watersheds with local chemical and physical conditions among the best in the region could still be considered reference. The use of biological data for screening was avoided over concerns of circularity. For the same reason, physical habitat observations (e.g., riparian vegetation and streambed sediments) other than direct observations of human activities were not used to screen candidate reference sites for assessing physical habitat condition.

Not every reference site had identical chemical, physical, biological indicator scores. A range of values was found at the reference sites within an ecoregion. This range of values was used to construct a reference site distribution. The 5th and

25th (or 95th and 75th) percentiles of the reference-site distributions were used as thresholds for assigning any individual site in the probability survey to a condition class, i.e., good, fair, or poor.

2.5 Indicators of condition: biological quality

Samples of the macroinvertebrate and fish assemblages formed the basis for assessing the biological quality of streams and rivers. Only the macroinvertebrate assemblage results are presented here, although similar results are available for fish. Diatom assemblage samples were collected and analyzed and as of this writing, and taxonomic consistency issues are being resolved.

Two measures of the macroinvertebrate assemblage were used to communicate biological quality: a multimetric index (MMI) of macroinvertebrate integrity [10] and an observed/expected (O/E) index of taxa loss [11]. The MMI was developed for each of the nine aggregated ecoregions and compared with the reference conditions determined for that ecoregion [42].

O/E indices of taxa loss were also calculated. These are interpreted as the percentage of the expected taxa present at a site. Each tenth of a point less than 1 represents a 10% loss of taxa, e.g., an O/E value of 0.9 indicates 90% of the expected taxa are present and 10% are missing. Three O/E models were developed, one for each of the major climatic regions (**Figure 2A**): The Eastern Highlands, the Plains and Lowlands, and the West [11, 44]. Four categories of taxa loss were calculated: < 10% loss, 10–20% loss, 20–50% loss, and >50% taxa loss.

2.6 Indicators of stressors impacting streams and rivers

River and stream biota can be adversely impacted when alterations occur within the watershed or within the stream and river itself. The in-stream and riparian characteristics that are altered as a result of human activity and in turn result in biotic changes are considered "stressor indicators". These resulting aquatic stressors can be chemical [45], physical, or in some cases, biological [46]. Importantly, the goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's water resources. The NRSA has a dual purpose in generating data on chemical, physical, and biological stressors. The first purpose uses these data in describing chemical and physical integrity of rivers and streams as a means of tracking progress toward the goals of the CWA. The second purpose uses these data to rank the stressors in their relative importance for policy. Ranking occurs in three ways. The first way establishes how widespread the stressors are. The second way ranks stressors by their severity when they occur, i.e., how likely are they to impact biota. And the third way, perhaps the most important, ranks stressors based on the likely improvement in rivers and streams if that stressor is reduced or eliminated. Not every potential chemical or physical stressor is currently included in the NRSA reports on condition, but both present and future surveys of rivers and streams in the US should include measurements that enable assessments of additional stressors for which there is reasonable concern that they may become important in the future.

The NRSA stressor indicators are the proximal stressors, i.e., changes in chemical or physical attributes that can affect biota. The stressors are not the more distal measures such as basin land-use or land-cover alterations not directly observed by the field crews, e.g., row crops, mining, or grazing visible in satellite imagery. This approach asserts that many human activities on the landscape can be sources of pollutants or indirect causes of stress to streams. However, the focus of the NRSA is to identify and quantify the stressors, rather than their sources. The general philosophy was to understand the most significant stressors first. This information can be used in the process of source tracking and determining probable causes, which are logical future steps for the NRSA and similar national assessments.

Eight stressor indicators were selected for reporting. Four stressors were chemical, and four were related to habitat alterations. The chemical stressors were excess total nitrogen (total N), excess total phosphorus (total P), excess salinity (based on conductivity), and acidification (based on acid neutralizing capacity). Prior 305(b) reports from States or national attention were the basis for these selections. Indicators of habitat alteration have not historically been included in monitoring by most water quality agencies. With a focus on the CWA goals, physical integrity became a needed element within NARS. Four indicators of physical integrity, excess fine sediments, alterations of instream fish habitat, alteration of riparian vegetation structure, and disturbance of the riparian zone are the initial focus. A fifth, hydrologic alteration is near completion.

2.7 Ranking of stressors: relative extent and relative risk

An important prerequisite to making policy and management decisions is an understanding of the relative magnitude or importance of potential stressors across a region and the expected benefit of reducing or eliminating that stressor. Both the prevalence (i.e., extent of stream length with high levels of the stressor) and the severity (i.e., impact on biological condition) of each stressor were considered. The NRSA reports include separate ranking for each of these elements, extent and risk.

Relative extent is a measure of how widespread the problem is…how much of the river and stream length has high levels of that particular stressor. Does high nitrogen occur in few or in many streams and rivers? Are high nitrogen levels geographically isolated or widespread? Relative risk, on the other hand, addresses the severity of the impact of high nitrogen on the biota when it occurs as compared to when nitrogen levels are low. Neither of these measures individually is a good indication that the problem should be addressed. But when combined, they provide powerful evidence of the need to act.

3. Results

Fish, macroinvertebrates and periphyton samples were all collected during the 2013–2014 stream and river survey. The data were processed and assessed and can be found in the detailed online dashboard and report [47]. Here we present the results for just the macroinvertebrate assemblage as an example of data generated by the NRSA.

3.1 Benthic macroinvertebrate conditions (MMI)

Nationally, 44% of the perennial stream and river length (hereafter simply referred to as "stream length") was in poor condition, and 26% was in fair condition as measured by the benthic macroinvertebrate MMI relative to the least-disturbed reference condition in each of the nine aggregated ecoregions (**Figure 3**). Based on the MMI, 42% of stream length in the Eastern Highlands, 47% of stream length in the Plains and Lowlands, and 31% of stream length in the West were in poor condition. Detailed examples of results for the nine aggregated ecoregions for the 2008–2009 NRSA are available elsewhere [28, 48].

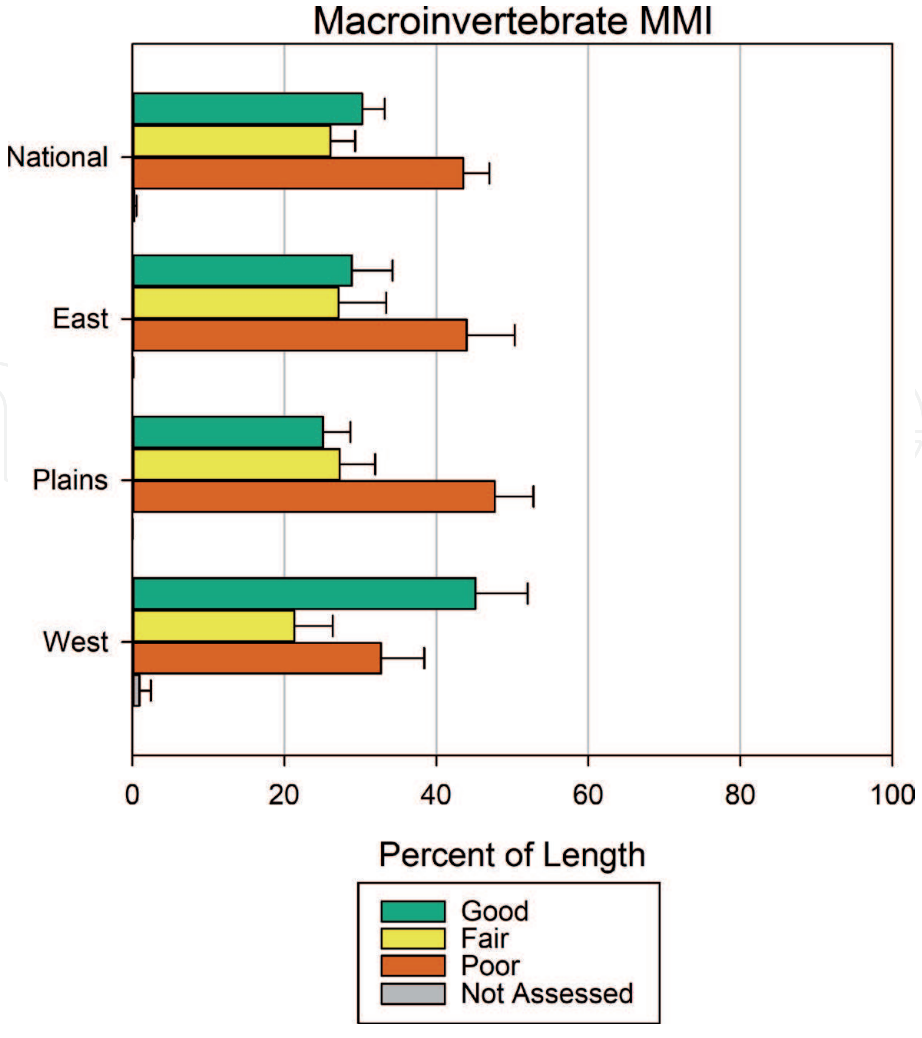

Figure 3.
National and regional results from the 2013–2014 National Rivers and Streams Assessment for the benthic macroinvertebrate multimetric index (MMI). Results are presented as the percent of stream length in good, fair and poor conditions, based on the degree of similarity to regionally-defined reference condition. Error bars represent 95% confidence intervals.

3.2 Benthic macroinvertebrate taxa (O/E index)

Nationally, 46% of stream length lost <10% of expected taxa, 13% lost 10–20%, 26% of stream length lost 20–50%, and 15% of stream length lost >50% of expected taxa (**Figure 4**). The Eastern Highlands experienced the greatest loss of expected taxa; 21% of stream length lost >50%, 29% of length lost 20–50% of expected taxa, 10% of length lost 10–20% of taxa, and 40% of stream length lost <10% of expected taxa.

3.3 Relative extent of stressors

High levels of several stressors occurred throughout perennial streams and rivers. Excess total phosphorus was the most widespread stressor nationally and within each region. Fifty-eight percent of the river and stream length are marked by high total phosphorus concentrations across the country (**Figure 5A**). The prevalence in the Plains and Lowlands, Eastern Highlands and the West is 51, 73 and 49%, respectively.

Nutrients (total phosphorus and total nitrogen) were consistently the most extensively occurring stressors with the stream length in poor condition ranging

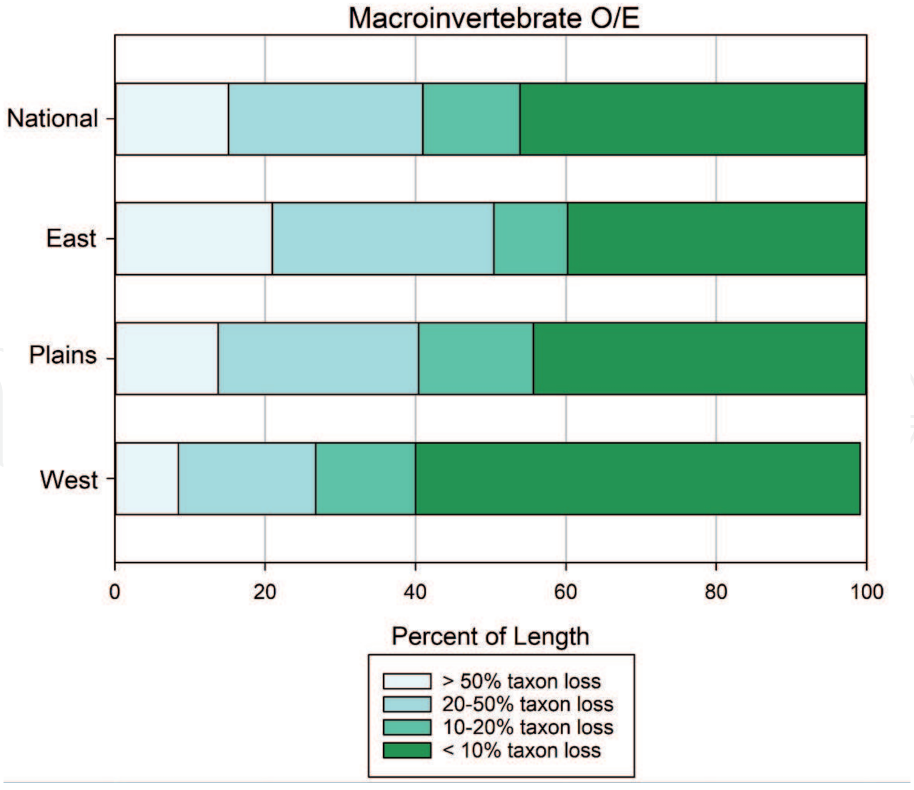

Figure 4.
National and regional results from the 2013–2014 National Rivers and Streams Assessment for the benthic macroinvertebrate observed/expected (O/E) index of taxon loss. Results are presented as the percent of stream length in four categories of taxon loss.

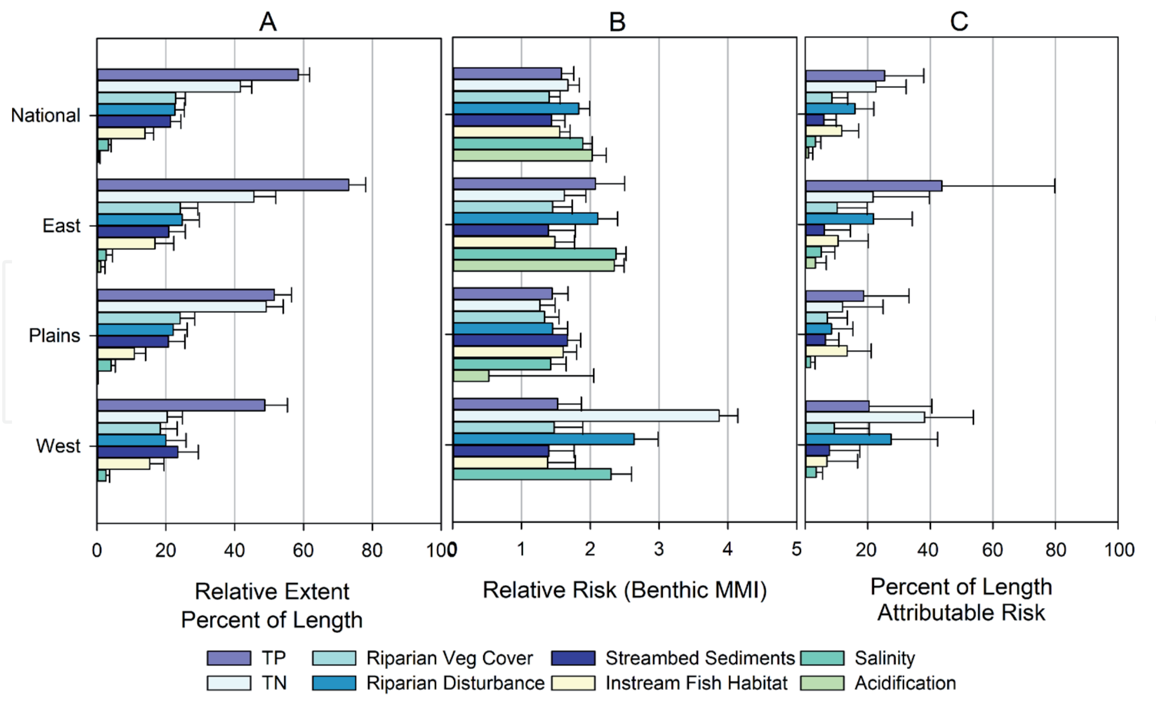

Figure 5.
Relative ranking of stressors nationally and regionally for the 2013–2014 National Rivers and streams assessment. (A) Relative extent is the percent of stream length in poor condition for each of the eight stressors evaluated. (B) Relative risk of observing poor biological condition (based on values of the benthic invertebrate multimetric index [MMI]) given poor stressor conditions relative to observing poor MMI values given good or moderate stressor conditions. (C) Attributable risk is the percent of improvement (i.e., decrease) in stream length in poor biological condition (based on MMI scores) given that a stressor level is modified from poor to good or fair condition. Error bars represent 95% confidence intervals.

from about 20% to about 75% across the three major regions (**Figure 5A**). Poor conditions for the four physical habitat indicators were observed in about 20% of stream length nationally, but ranged from 10 to 25% across the three climatic regions. There was much more variability in physical habitat condition at the finer ecoregion scale, with 4 to 40% of stream length in poor condition among the 9 ecoregions, depending on the specific physical habitat indicator and region. Alteration of riparian vegetation cover was the most extensive habitat stressor nationally and in the Eastern Highlands and the Plains and Lowlands regions. High levels of excess fine sediments were most prevalent in the West.

3.4 Relative risk of stressors

Almost all stressors evaluated in the NRSA were associated with increased risk for poor macroinvertebrate condition (**Figure 5B**). Nationally, the relative risk values ranged from 1.4–2.0, with only slight or no substantial difference among the stressors nationally. In fact, two of the stressors, acidification and increased salinity, had among the largest relative risk values.

Relative risk values differed among major NRSA regions (**Figure 5B**). The largest relative risk value (3.9) occurred for total nitrogen in the West, showing that streams with excess total nitrogen were nearly 4 times more likely to have their benthic macroinvertebrate assemblage in poor condition when compared to streams with moderate or low concentrations of total nitrogen. All the stressors posed a risk to macroinvertebrate biological integrity with relative risks values ranging from 1.3 to 3.9 nationally and in all three geoclimatic regions.

3.5 Attributable risk - combining stressor extent and relative risk

As described above, the use of relative extent and relative risk in combination provides the best assessment of a particular stressor. It provides an estimate of the relative improvement in the biota with the reduction of that stressor (**Figure 5A–C**). Rivers and streams are at greatest risk when the stressor is both widespread (large percentage of river and stream length with stressor at excess levels, **Figure 5A**) and presents potentially severe effects (i.e., high relative risk values, **Figure 5B**). Another tool from epidemiology, the concept of attributable risk, was adapted and applied to the data from the Wadeable Streams Assessment [49], and is now part of all of assessments produced from the NRSA surveys. Attributable risk combines relative extent with relative risk to produce a single number that can be used to rank stressors and to inform management decisions by suggesting the level of improvement expected (in terms of the % of stream length in poor biological condition that could be elevated to good condition) if excess levels of a particular stressor are reduced to moderate or low levels.

Nationally, excess total nitrogen and total phosphorus are the stressors whose relative extent (how widespread) and relative risk (severity of impact when excess levels occurred) suggest the largest expected improvement. For each of these nutrients, roughly a 25% improvement (i.e., decrease) in the stream length in poor biological condition is expected if levels of these nutrients are reduced from excess to moderate or low (**Figure 5C**). Excess fine sediments and alteration of the riparian vegetation were the habitat stressors that would produce the largest expected improvement in stream and river biological condition (a 16 and 12% improvement, respectively). Salinity occurs in excess levels in a very low percentage of stream length (**Figure 5A**) and despite high relative risk (**Figure 5B**), this stressor has a very small attributable risk. Thus, excess salinity might be considered a local issue requiring a local targeted management approach, severe when it occurs, yet not of significance at a national or regional scale.

4. Conclusions

The NRSA surveys began in early 2000s and were repeated in 2008–2009, 2013–2014 and most recently in 2018–2019. The results of the NRSA and the data on which they are based constitute a baseline from which future trends can be evaluated. The NRSA survey has been repeated enough that detecting changes and trends in status are now possible using the NRSA approach. Stoddard et al. [50] demonstrated the NRSA's capability for detecting changes and trends when they reported a consistent increase in total phosphorus concentration and a loss of low nutrient waters across surveys in the period of 2004 and 2014. As the number of resurveys mounts up over time, results from trend detection and analyses will increase, becoming a more and more critical contribution of the NRSA results and the NARS in general.

Although the set of important stressors currently assessed by NRSA appears robust for long-term trends in important known stresses on biological integrity, there is room for innovation and inclusion of new and relevant indicators of stress. There is also room for integration of new monitoring technologies such as DNA sequencing, LIDAR and new satellite-based sensor technology.

The NRSA was the first and is still the only comprehensive national assessment of water resources conducted in the US that is based on uniform, consistent field protocols and a statistically robust sampling design. The NRSA statistical design is a major advancement in aquatic monitoring and has been embraced by multiple States and Federal Agencies. The NRSA statistical design and many NRSA field sampling methods and analytical approaches have been applied or adapted to monitoring and assessment within US states and worldwide (Canada, Brazil, Bolivia, Belize, and China). The CWA goals of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters imply that we would have the required monitoring to track our progress toward meeting those goals. The NRSA and the other surveys within the NARS, as well as those States and other agencies adopting the NARS tools, are beginning to deliver on that implicit promise.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] Shapiro MH, Holdsworth SM, Paulsen SG. The need to assess the condition of aquatic resources in the US. Journal of the North American Benthological Society. 2008;**27**(4):808-811

[2] Harris G. Inland Waters Theme Commentary Prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, Australia. 2006. Available from: http://www.deh.gov.au/soe/2006/commentaries/water/index.html

[3] State of the Environment Advisory Council. Australia: State of the Environment 1996. An Independent Report Presented to the Commonwealth Minister for the Environment. Collingwood, Victoria Australia: CSIRO Publishing; 1996. 502 + 47 p

[4] Ball J, Donnelly P, Erlanger P, Evans R, Kollmorgon A, Neal B, et al. Inland Waters. Australia State of the Environment Report 2001 (Theme Report). CSIRO, Department of the Environment and Heritage: Canberra, Australia; 2001

[5] Hering D, Borja A, Carstensen J, Carvalho L, Elliott M, Feld CK, et al. The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. Science of the Total Environment. 2010;**408**(19):4007-4019

[6] Hering D, Verdonschot PFM, Moog O, Sandin L. Preface. Hydrobiologia. 2004;**516**(1):7-9

[7] Norris RH, Morris KR. The need for biological assessment of water quality: Australian perspective. Australian Journal of Ecology. 1995;**20**(1):1-6

[8] Simpson JC, Norris RH. Biological assessment of river quality: Development of AUSRIVAS models and outputs. In: Wright JF, Sutcliffe DW, Furse MT, editors. Assessing the Biological Quality of Freshwaters: RIVPACS and Other Techniques. Ambleside, Cumbria, U.K.: Freshwater Biological Association; 2000. pp. 125-142

[9] Hering D, Moog O, Sandin L, Verdonschot PFM. Overview and application of the AQEM assessment system. Hydrobiologia. 2004;**516**:1-20

[10] Stoddard JL, Herlihy AT, Peck DV, Hughes RM, Whittier TR, Tarquinio E. A process for creating multimetric indices for large-scale aquatic surveys. Journal of the North American Benthological Society. 2008;**27**(4):878-891

[11] Yuan LL, Hawkins CP, Van Sickle J. Effects of regionalization decisions on an O/E index for the US national assessment. Journal of the North American Benthological Society. 2008;**27**(4):892-905

[12] Olsen AR, Peck DV. Survey design and extent estimates for the Wadeable streams assessment. Journal of the North American Benthological Society. 2008;**27**(4):822-836

[13] Paulsen SG, Hughes RM, Larsen DP. Critical elements in describing and understanding our nation's aquatic resources. Journal of the American Water Resources Association. 1998;**34**(5):995-1005

[14] Federal Water Pollution Control Act - Amendments of 1972., Pub. L. No. 33 U.S.C. §1251 et seq. (1972)

[15] National Research Council. Environmental Monitoring, Volume IV. Washington, DC: National Academy of Sciences; 1977

[16] National Research Council. Linking Science and Technology to Society's Environmental Goals. Washington, DC: The National Academies Press; 1996. p. 544

[17] GAO (Government Accountability Office). Better monitoring techniques are needed to assess the quality of rivers and streams. Volume 1. Washington, DC: Community, and Economic Development Division, Government Accountability Office; 1981. Report No.: GAO/CED–81-30

[18] GAO (Government Accountability Office). Water quality: key EPA and State decisions limited by inconsistent and incomplete data. Gaithersburg, Maryland: Resources, Community, and Economic Development Division, Government Accountability Office; 2000. Report No.: GAO/RCED–00-54

[19] GAO (U.S. General Accounting Office). Protecting human health and the environment through improved management. Gaithersburg, Maryland: Resources, Community, and Economic Development Division, General Accounting Office; 1988. Report No.: GAO/RCED–88-101

[20] USEPA (United States Environmental Protection Agency). Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrometry. Draft Method 7473. Washington, DC: EPA; 1998

[21] H. John Heinz Center for Science, Economics, the Environment. The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States. New York: Cambridge University Press; 2002. p. 288

[22] Environmental Mysteries. USA Today. 2002 September 26. 2002

[23] Stoddard JL, Peck DV, Paulsen SG, Van Sickle J, Hawkins CP, Herlihy AT, et al. An Ecological Assessment of Western Streams and Rivers. Washington, DC, Office of Research and Development, US Environmental Protection Agency; 2005 Report No.: EPA 620/R-05/005

[24] Paulsen SG, Mayio A, Peck DV, Stoddard JL, Tarquinio E, Holdsworth SM, et al. Condition of stream ecosystems in the US: An overview of the first national assessment. Journal of the North American Benthological Society. 2008;**27**(4):812-821

[25] US Coast Guard. Federal Requirements for Recreational Boats. Washington, DC: U.S. Department of Transportation, United States Coast Guard; 1987

[26] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2008-2009 Technical Report. Washington, DC: Office of Water and Office of Research and Development, US Environmental Protection Agency; 2016. Report No.: EPA 841/R-16/008

[27] McKay L, Bondelid T, Dewald TG, Johnston J, Moore R, Rea A. NHDPlus Version 2: User Guide (Data Model Version 2.2, updated March 13, 2019). Washington, DC: U.S. Environmental Protection Agency, Office of Water; 2012

[28] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2008-2009: A Collaborative Survey. Washington, DC: Office of Water and Office of Research and Development, US Environmental Protection Agency; 2016. Report No.: EPA 841/R-16/007

[29] USEPA (United States Environmental Protection Agency). Visiting a Regional Office webpage. Washington, DC: U.S. Environmental Protection Agency; 2020; Available

from: https://www.epa.gov/aboutepa/visiting-regional-office [Accessed: 13 March 2020]

[30] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment. A Collaborative Survey. Washington, DC: Office of Water and Office of Research and Development, US Environmental Protection Agency; 2013-2014 in press

[31] Hughes RM, Peck DV. Acquiring data for large aquatic resource surveys: The art of compromise among science, logistics, and reality. Journal of the North American Benthological Society. 2008;**27**(4):837-859

[32] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2013/14: Field Operations Manual - Wadeable. Washington, DC: Office of Water and Office of Environmental Information; 2013. Report No.: EPA 841/B-12/009b

[33] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2013/14: Field Operations Manual - Non-Wadeable. Washington, DC: Office of Water and Office of Environmental Information; 2013. Report No.: EPA 841/B-12/009a

[34] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2013-14: Quality Assurance Project Plan, v. 2.1. Washington, DC: U.S. Environmental Protection Agency, Office of Water; 2015. Report No.: EPA 841-B-12-007

[35] Stribling JB, Pavlik KL, Holdsworth SM, Leppo EW. Data quality, performance, and uncertainty in taxonomic identification for biological assessments. Journal of the North American Benthological Society. 2008;**27**(4):906-919

[36] USEPA (United States Environmental Protection Agency). National Rivers and Streams Assessment 2013-2014: Laboratory Operations Manual (Version 2.0). Washington, DC: Office of Water; 2014. Report No.: EPA-841-B-12-010

[37] USEPA (United States Environmental Protection Agency). Wadeable Streams Assessment: Field Operations Manual. Washington, DC: Office of Water; 2004. Report No.: EPA 841/B-04/004

[38] Carlisle DM, Hawkins CP. Land use and the structure of western US stream invertebrate assemblages: Predictive models and ecological traits. Journal of the North American Benthological Society. 2008;**27**(4):986-999

[39] Ode PR, Hawkins CP, Mazor RD. Comparability of biological assessments derived from predictive models and multimetric indices of increasing geographic scope. Journal of the North American Benthological Society. 2008;**27**(4):967-985

[40] Stoddard JL, Larsen DP, Hawkins CP, Johnson RK, Norris RH. Setting expectations for the ecological condition of streams: The concept of reference condition. Ecological Applications. 2006;**16**:1267-1276

[41] Hawkins CP, Olson JR, Hill RA. The reference condition: Predicting benchmarks for ecological and water-quality assessments. Journal of the North American Benthological Society. 2010;**29**(1):312-343

[42] Herlihy AT, Paulsen SG, Sickle JV, Stoddard JL, Hawkins CP, Yuan LL. Striving for consistency in a national assessment: The challenges

of applying a reference-condition approach at a continental scale. Journal of the North American Benthological Society. 2008;**27**(4):860-877

[43] Davies SP, Jackson SK. The biological condition gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications. 2006;**16**(4):1251-1266

[44] USEPA (United States Environmental Protection Agency). Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams. Washington, DC: Office of Water, US Environmental Protection Agency; 2006. Report No.: EPA 641/B-06/002

[45] Herlihy AT, Sifneos J. Developing nutrient criteria and classification schemes for wadeable streams in the conterminous USA. Journal of North American Benthological Society. 2008;**27**(4):932-948

[46] Ringold PL, Magee TK, Peck DV. Twelve invasive plant taxa in US western riparian ecosystems. Journal of the North American Benthological Society. 2008;**27**(4):949-966

[47] USEPA. National Rivers and Streams Assessment Webpage. Washington, DC: U.S. Environmental Protection Agency; 2018; Available from: https://www.epa.gov/national-aquatic-resource-surveys/nrsa

[48] USEPA. National Rivers and Streams Assessment 2008-2009 Results Webpage. Washington, DC: U.S. Environmental Protection Agency. p. 2018; Available from: https://www.epa.gov/national-aquatic-resource-surveys/national-rivers-and-streams-assessment-2008-2009-results

[49] Van Sickle J, Paulsen SG. Assessing the attributable risks, relative risks, and regional extents of aquatic stressors. Journal of the North American Benthological Society. 2008;**27**(4):920-931

[50] Stoddard JL, Van Sickle J, Herlihy AT, Brahney J, Paulsen S, Peck DV, et al. Continental-scale increase in lake and stream phosphorus: Are oligotrophic systems disappearing in the United States? Environmental Science & Technology. 2016;**50**(7):3409-3415