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Evaluating Clean Water Act progress drivers for Idaho rivers and streams 2002-2022

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Abstract

In the United States, the Clean Water Act (CWA) is the primary legislation driving surface water quality management. Its goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Section 305(b) of the CWA requires states to document CWA progress by reporting whether applicable water quality standards are achieved for all state waters every two years. Developing strategies for increasing the proportion of waters achieving standards requires diagnosing factors driving 305(b) data temporal trends. This analysis demonstrates how systematically analyzing 305(b) data in new ways can help document CWA progress (or lack thereof) and associated drivers. Idaho 305(b) data were used to evaluate the relative contribution of assessment progress and restoration to 2002-2022 Idaho 305(b) temporal trends. Assessment progress was defined as assessing unassessed waters and correcting assessment errors. Restoration was defined as changes from not achieving to achieving all assessed standards because water quality improved. From 2002-2022, the percentage of Idaho stream kilometers achieving all assessed standards increased from 24% to 32%. Systematically evaluating reasons for stream status changes revealed this trend was driven primarily by assessment progress, specifically progress monitoring previously unassessed waters in good condition and correcting prior assessment errors. More stream km changed from impaired to unimpaired because prior assessment errors were corrected than because water quality improved; in each report $\leq$ 5% of all stream km changing status resulted from water quality improvement. As of 2022, more state stream km were impaired (39%) than unassessed (29%) and restoration success rates will likely become the primary driver of 305(b) temporal trends in the future. Systematically analyzing 305(b) data in new ways may help develop new empirically driven strategies for accelerating CWA progress and merits further investigation.

Introduction

In the United States, the Clean Water Act (CWA) is the primary legislation driving surface water quality management. The goal of the CWA is to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” [1]. The CWA establishes programs that the US Environmental Protection Agency (USEPA), states, and USEPA-authorized Native American tribes [2,3] must implement to achieve this goal. States must define water quality standards necessary to protect aquatic life, recreation, and other beneficial uses of water targeted for protection. USEPA reviews and either approves each state-established standard or disapproves and promulgates a standard. Administratively, the CWA goal is achieved for a water body when all applicable water quality standards are achieved and thereby beneficial uses of water targeted for protection are supported.

The CWA includes multiple provisions requiring states and USEPA to document progress towards achieving CWA goals. Section 305(b) requires states to submit a biennial report to USEPA documenting whether applicable water quality standards have been achieved for all state navigable waters, and USEPA to summarize and transmit this information to the U.S. Congress. Section 314 requires “an identification and classification according to eutrophic condition of all publicly owned lakes” to be included in state 305(b) reports. Section 303(d) requires states identify and develop priority rankings for impaired waters that require pollutant load reductions. Since 2002, USEPA has requested states submit a single biennial ‘Integrated Report’ (IR) that fulfills all three reporting requirements [4]. The CWA requires USEPA to review and either approve each state list of impaired waters requiring pollutant load reductions (§ 303(d) list) or disapprove and promulgate a modified list for the state [5,6].

State 305(b) data document whether each state water is impaired (not achieving one or more standards), unimpaired (achieving all assessed standards) or not assessed but also have several limitations. States do not have sufficient resources to monitor and assess all state waters and all applicable water quality standards every two years. Therefore, each state 305(b) report typically includes updated assessments for a subset of state standards in a small fraction of state waters. For each water body, water quality standards attainment decisions are typically based on targeted waterbody-specific monitoring for selected water quality standards. After a state has assessed a water body, its impairment status remains the same in subsequent biennial reports until new monitoring data become available and prompt an updated assessment. State 305(b) reports therefore may not reflect recent water quality data for all state waters, are not comprehensive, and 305(b) data patterns may not be representative of those in the entire population of state waters.

In response to these limitations, and to water quality standards and assessment methods inconsistencies across states, USEPA developed probabilistic monitoring survey methods to describe water quality status and trends at regional and national scales [7-10]. States use 305(b) data primarily to fulfill CWA reporting requirements and support local water quality management decisions. Some states also use state-scale probability surveys to estimate the percentage of state waters achieving specific water quality standards, describe the status of waters at the state scale based on bioassessment, or document state-scale patterns for parameters of interest [11-12]. USEPA used both state 305(b) data and national-scale probabilistic survey results to fulfill its 305(b) reporting requirements to Congress [13].

Although 305(b) data have limitations, analyzing 305(b) data trends is still important and useful. Even in states with state probabilistic monitoring surveys, states still typically use targeted nonrandom monitoring to assess if applicable standards are achieved in each water body. One sample event at one randomly located site within a water body from a probability survey is often not adequate for standards attainment decisions. Using targeted nonrandom monitoring to make waterbody-specific assessment decisions is important because standards attainment status triggers other CWA requirements with significant consequences. For example, for waters that don't achieve standards, the CWA requires states to develop a pollutant budget called a total maximum daily load (TMDL). A TMDL identifies pollutant loading levels needed to achieve water quality standards and the allowable contribution of point and nonpoint sources. Developing at TMDL can be an expensive, lengthy, and scientifically complex process. TMDLs can also have significant impacts on industries and ecosystems. The CWA also requires a permit for point source discharges. Permit requirements can be affected by standards attainment status for the water body receiving point source discharges. Therefore, identifying 305(b) data trends and associated drivers is not just an administrative exercise. Trend drivers also ultimately have downstream impacts on regulated communities, land management agencies, and ecosystems.

The objective of this study was to demonstrate how systematically analyzing 305(b) data in new ways can help document CWA progress (or lack thereof) and associated drivers. Idaho 2002-2022 305(b) data were used to document temporal trends for the percentage of Idaho river and stream (hereafter 'stream') kilometers (km) assessed, impaired (not achieving one or more water quality standards), and unimpaired (achieving all assessed water quality standards). Stream status changes across years were then systematically analyzed to evaluate the relative contribution of assessment progress and restoration to observed 305(b) temporal trends. 'Assessment progress' was defined as progress assessing unassessed waters and correcting assessment errors. 'Restoration' was defined as when a water body changes from not achieving to achieving all assessed standards because water quality improved. Results suggest novel systematic analyses of 305(b) data can help identify strategies for accelerating CWA progress.

Materials and Methods

Idaho Integrated Report Data

Data from all of Idaho's IRs since 2002 (2002, 2008, 2010, 2012, 2014, 2016, 2018/2020, and 2022) [14-21] were compiled to evaluate progress towards CWA goals for Idaho streams. Idaho did not publish a 2006 IR and combined its 2018 and 2020 IRs because of IR production and approval delays. In some cases, the Idaho Department of Environmental Quality (DEQ) did not produce an IR within the two-year window required by the CWA. In addition, prior to the 2018/2020 IR, USEPA took many months to issue an approval decision rather than the 30 days required by the CWA. DEQ and USEPA have since improved their IR processes and IRs were completed and approved on a biennial schedule since Idaho's 2016 IR. This study focused only on streams because, as of 2022, DEQ had assessed 71% of the state's >148,000 stream km using relatively consistent methods since 2002 [22,23] (Fig 1). State-scale temporal trends for percentage of lake and reservoir surface area impaired would be strongly biased by the relatively few large lakes and reservoirs that comprise most of state lake and reservoir surface area and are the primary focus of monitoring efforts. Out of 641 lake and reservoir systems in the state, the 47 that exceed 4 km^2 surface area represent 90% of total state lake and reservoir surface area.

Fig 1. Idaho river and stream status in Idaho's 2022 Integrated Report. The map was created from public data published by the Idaho Department of Environmental Quality (DEQ): https://www.arcgis.com/home/item.html?id=05678d2deccd485493676ced5c75fbbf

Starting with Idaho's 2002 IR, DEQ developed and managed IR data for streams using relatively consistent methods across years. Streams were delineated into discrete assessment units (AUs) based on National Hydrography Dataset version 2 (NHDPlus v2, 1:100 k resolution) [24]. Idaho's streams are divided into 5,065 stream AUs. AUs were delineated primarily based on stream order [25, 26], although land use, management, and ownership were also considered in some cases. Generally, 1st and 2nd order streams within a contiguous 12-digit hydrologic unit code subwatershed were lumped into a single AU, each 3rd and 4th order stream were a discrete AU, and streams ≥ 5th order were divided into multiple AUs. Compliance with water quality standards and beneficial use support were assessed following standardized agency guidance [22, 23] and methods described in IR documents [14-21]. DEQ managed and reported IR data using Microsoft Excel for the 2002 IR, using USEPA's Assessment Database (ADB) software [27] for 2008-2016 IRs, and using EPA's cloud-based Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS) software [28] for the 2018/2020 and 2022 IRs. Data compilation methods and associated quality assurance checks, compiled data, and R code used for analyses are included in supporting information.

In each IR cycle, DEQ used recent (< 5 years old) data to assess support of beneficial uses. Data used included DEQ data, data submitted by external entities for the IR through a public call for data, and readily available public data. A data quality screening process was used to determine if external data had sufficient rigor and documentation to be used for assessments [22,23]. Generally, DEQ's assessment process for each AU was as follows. Beneficial uses of water requiring protection were identified based on Idaho water quality standards [29]. Any available water chemistry data that passed data quality screening processes were compared to applicable water quality standards. In addition, if available within the AU, data collected through

DEQ's Beneficial Use Reconnaissance Program (BURP) bioassessment program were used to assess support of cold water aquatic life beneficial use. Using a targeted non-random monitoring design, DEQ has collected BURP data in over 200 wadable 1st-4th order stream reaches throughout Idaho each year in most years since 1993 [30-31]. Multiple fish, habitat, and macroinvertebrate metrics measured by the BURP program are compared to those in reference streams with a similar physiographic setting to assess support of cold-water aquatic life use based on BURP data. Detailed assessment methods are described in Idaho's waterbody assessment guidance [22,23] and IR documents. For each assessed AU, each assessed beneficial use requiring protection was classified as either not assessed, not supporting, or fully supporting, and the cause(s) of impairment was determined based on which monitored parameter(s) violated water quality standards. Within each IR cycle, beneficial uses assessed varied across AUs depending on which uses applied and data were available. Once an AU was assessed, beneficial use support status remained the same in subsequent IR cycles unless new data prompted a revised assessment.

Starting with Idaho's 2018/2020 Integrated Report, DEQ split all AUs crossing federally recognized Native American reservation boundaries to create separate AUs inside and outside the boundary. All AUs within federally recognized reservation boundaries were reported as "not assessed" to comply with an Idaho tribal waters policy developed collaboratively by DEQ, EPA, and Idaho Native American tribes [19]. Child AUs outside the reservation boundary resulting from the split generally retained the impairment status of the parent AU prior to the split. When the policy was implemented, 3.6% of stream km were inside a reservation and therefore classified as not assessed. In addition, since the 2002 IR, DEQ has assessed AUs entirely within federally designated Wilderness or certain roadless area categories with no readily available monitoring data as unimpaired. For these AUs, DEQ presumed all beneficial uses are supported due to limited anthropogenic watershed disturbance. Across the 2002-2022 IRs, 4.3-6.7% of stream km were presumed unimpaired.

CWA Progress Temporal Trends

CWA progress temporal trends were evaluated by calculating the percentage of stream km assessed, impaired, and unimpaired within each IR reporting cycle. Streams were impaired if one or more applicable water quality standards were exceeded, and unimpaired if all assessed water quality standards were achieved. For this analysis, streams within reservation boundaries were included when calculating total state stream km and the percentage of km by status prior to implementation of the tribal waters policy (2002-2016 IRs). Streams within reservation boundaries were excluded for calculations after implementation of the tribal waters policy (2018/2020 IRs). This approach was selected to be consistent with policy implementation history. Tribal waters policy implementation had minimal effect on state-wide temporal stream impairment trends and trend driver patterns (see results).

Trend Drivers

Temporal trend drivers were evaluated by systematically analyzing AU status change reasons. For 2008-2022 IR cycles, each AU/cycle combination was assigned to one change reason class based on if and how AU impairment status changed from the prior cycle. An AU had ‘no change’ if its impairment status (not assessed, impaired, unimpaired) did not change from the prior cycle. Otherwise, AU status change was classified as either ‘restored (impaired to unimpaired)’, or into one of several classes representing assessment progress: ‘not assessed to impaired’, ‘not assessed to unimpaired’, ‘unimpaired to impaired’, ‘impaired to not assessed’ or ‘unimpaired to not assessed’. The number and percentage of stream km within each change reason class were calculated for each IR.

Streams classified as ‘restored (impaired to unimpaired)’ potentially represent cases where the CWA goal of restoring water quality was achieved. However, AUs may also change from impaired to unimpaired because the original impairment decision was incorrect rather than because water quality improved. The original impairment decision can be incorrect if water quality data were associated with the wrong AU, assessment protocols were applied incorrectly, or improved monitoring or assessment methods indicated the original impairment decision was incorrect. For each AU changing from impaired to unimpaired, available documentation was reviewed. Each IR 2008-2022 included a ‘delisted waters’ appendix documenting AU/cause combinations changing from impaired to not impaired. For each case, the appendix included text justifying for the change that was USEPA reviewed as part of its 303(d) list approval decisions. Delisting justification text, along with other relevant documentation when available, were reviewed and the status change reason was classified as ‘original assessment incorrect’, ‘water quality standards attained’, or ‘unclear’. Change reasons were classified as ‘unclear’ if available information was insufficient to assign a change reason. The number and percentage of stream km changing from impaired to unimpaired for each reason was calculated for each IR cycle.

Results and Discussion

From 2002-2022, the percentage of Idaho stream km assessed increased from 59% to 71% (Fig 2). Concurrently, the percentage of impaired km increased from 35% to 39%, and the percentage of unimpaired km increased from 24% to 32% (Fig 2). Because calculated percentages were based on targeted nonrandom monitoring, they may not be representative of the entire population of state streams. A comprehensive and unbiased estimate of the percentage of state stream km unimpaired and impaired would require collecting monitoring data needed to assess each of Idaho's >100 water quality criteria using a probabilistic survey design. Although EPA's probabilistic stream monitoring programs included Idaho streams, they were not designed to assess compliance with Idaho water quality standards; they were designed to generate unbiased estimates for the percentage of stream km in EPA-defined 'good', 'fair', or 'poor' condition classes at the regional and national scale [32]. During 2013 and 2015, DEQ's Idaho Wadable Streams Survey collected BURP data using a probabilistic design to estimate the percentage of state 1st-4th order wadable stream km supporting cold water aquatic life use (71.2% supporting, 28.8% not supporting) [19]. However, the survey evaluated support of only one beneficial use (cold water aquatic life) for a subset of Idaho streams based only on BURP data. In contrast, percentages calculated here are based on all readily available data and assessed beneficial uses across all Idaho streams. Although percentages calculated here may not be representative of the entire population of state waters, they are still useful; systematically analyzing 305(b) data can help identify programmatic reasons for CWA progress (or lack thereof) and complement probabilistic surveys.

Fig 2. Percentage of Idaho stream km assessed, impaired, and not impaired.

Table 1. Percentage of stream km changing status by status change class during each integrated report cycle.

	Status Change Class	2008	2010	2012	2014	2016	2018/ 2020	2022
1	no change	88.1	93.8	96.8	96.2	96.5	98.1	96.1
2	unimpaired to impaired	2.0	1.2	0.6	0.1	0.7	0.3	2.7
3	not assessed to impaired	2.1	0.7	0.5	0.3	0.3	0.2	0.7
4	not assessed to unimpaired	3.6	2.0	1.6	2.3	1.0	0.9	0.3
5	assessed to not assessed	1.2	1.2	0.4	0.2	1.0	0.1	0.05
5a	impaired to not assessed	1.0	1.2	0.04	0.2	0.1	0.06	0
5b	unimpaired to not assessed	0.2	0	0.3	0	0.9	0.06	0.05
6	restored (impaired to unimpaired)	3.0	1.1	0.2	0.9	0.4	0.5	0.05
6a	water quality standards attained	0.5	0.1	0.02	0.1	0.1	0.1	0.01
6b	original assessment was incorrect	0.2	0.9	0.2	0.7	0.3	0.4	0.04
6c	reason unclear	2.3	0.2	0.01	0.1	0.02	0	0
	status change total (∑2-6)	11.9	6.2	3.3	3.8	3.4	2.0	3.8
	newly assessed (∑3,4)	5.7	2.7	2.1	2.6	1.3	1.1	1.0
	newly impaired (∑2,3)	4.1	1.9	1.1	0.4	1.0	0.5	3.4
	assessment-driven status change (∑2-5)	8.9	5.1	3.1	2.9	3.0	1.5	3.7
	corrected assessment errors (∑5, 6b)	1.4	2.1	0.6	0.9	1.3	0.5	0.09

Table 2. Stream km changing status by status change class during each integrated report cycle.

	Status Change Class	2008	2010	2012	2014	2016	2018/ 2020	2022
1	no change	133,190	143,799	148,161	147,673	148,077	145,348	142,425
2	unimpaired to impaired	3,054	1,843	866	228	1,133	419	4,070
3	not assessed to impaired	3,246	1,055	695	428	469	258	982
4	not assessed to unimpaired	5,435	3,045	2,410	3,508	1,618	1,270	515
5	assessed to not assessed	1,800	1,830	585	267	1,519	176	80
5a	impaired to not assessed	1,565	1,830	69	256	128	85	0
5b	unimpaired to not assessed	235	0	516	11	1,391	91	80
6	restored (impaired to unimpaired)	4,473	1,766	362	1,335	610	684	77
6a	water quality standards attained	799	145	37	147	182	111	19
6b	original assessment was incorrect	333	1,333	309	1,100	383	572	58
6c	reason unclear	3,445	288	16	87	44	0	0
	status change total (∑2-6)	18,008	9,539	4,918	5,766	5,349	2,807	5,724
	newly assessed (∑3,4)	8,681	4,100	3,105	3,936	2,087	1,528	1,497
	newly impaired (∑2,3)	6,300	2,898	1,561	656	1,602	677	5,052
	assessment-driven status change (∑2-5)	13,535	7,773	4,556	4,431	4,739	2,123	5,647
	corrected assessment errors (∑5, 6b)	1,898	3,163	378	1,356	511	657	58

Note: the total number of state stream km varies slightly across cycles due to NHDPlus v2 hydrography changes and implementation of the tribal waters policy starting in the 2018/2020 IR.

Idaho 305(b) temporal trends (Fig 2) were driven primarily by assessment progress rather than restoration. Assessment-driven status changes accounted for ≥ 75% of all stream km changing status each cycle (Table 1, Table 2). The percentage of stream km changing due to assessment progress was at least 3 times greater than percentage of km changing from impaired to unimpaired each cycle. In addition, the observed increase in percentage of unimpaired stream km was driven primarily by progress monitoring previously unassessed waters in good condition. More stream km changed from not assessed to unimpaired than for any other change reason in 6 out of 7 IR cycles. Monitoring previously unassessed waters in good condition also prompted more status changes than restoration. In each cycle fewer stream km changed from impaired to unimpaired than changed from not assessed to unimpaired (Table 1). In each report ≤ 5% of all status changes were due to water quality improvement. Correcting assessment errors was the primary reason streams changed from impaired to unimpaired rather than water quality improvement. Less than 25% of stream km changing from impaired to unimpaired each cycle changed status because water quality improved. In all reporting cycles except 2008, more stream km changed from impaired to unimpaired because the original impairment decision was incorrect than because water quality improved (Table 2). For the 2008 IR, this study classified the restoration reason as 'unclear' for many streams because limited or unclear status change justification was included in the 2008 IR. Restoration reasons were classified as unclear for a much smaller fraction of waters later cycles as IR data management and documentation practices improved (Table 1).

Assessment errors were common. Status changes due to assessment error correction include streams changing from impaired to not assessed, not impaired to not assessed, and changing from impaired to not impaired because assessment errors were corrected. Together, these represented 2-38% of all stream km changing status per cycle, and 2-43% of all assessment-driven changes each cycle (Table 1). The relatively high assessment error rate is partly a legacy of coarse assessment methods used prior to 2002 and is probably not unique to Idaho. Historically, inadequate monitoring and assessment methodology often led to inaccurate assessments by states [33-35]. For example, focus on water chemistry measures rather than biological indicators led to inaccurate biological impairment conclusions in Ohio [33]. In 2000, the U.S. Congress commissioned the National Research Council (NRC) to evaluate the scientific basis for CWA assessment and TMDL processes [36]. The NRC report concluded "many waters now on state 303d lists were placed there without the benefit of adequate water quality standards, data, or waterbody assessment" [36]. Because of monitoring and assessment challenges, NRC recommended USEPA allow states to develop a both a 'preliminary list' of potentially impaired waters needing further investigation separate from the list of impaired waters required by the CWA (303(d) list) [36]. USEPA did not implement this recommendation. USEPA IR guidance does not allow states to develop a preliminary list [4,37].

Attempts to develop a preliminary list in Idaho resulted in litigation. Idaho's 1992 303(d) list excluded a list of waters DEQ identified as impaired but requiring further assessment [38]. Citizens groups successfully sued USEPA for approving Idaho's 1992 303(d) list because it was incomplete and did not adequately consider all readily available water quality data [39]. A court order led to USEPA promulgating a revised version of Idaho's 1994 303(d) list that increased the number of 303(d)-listed water bodies on Idaho's 1994 303(d) list from 62 to 962 and established a timeline for developing TMDLs for these waters [39,40]. While subsequent monitoring and assessment confirmed many added waters were impaired, USEPA also added some waters based on failure to meet water quality objectives established by partner agencies such as the U.S.

Forest Service rather than based on compliance with Idaho water quality standards [40]. In some cases, impairment decisions were based on qualitative assessments or public desire to maintain existing water quality for certain waters [40]. Based on delisting documentation reviewed for restored waters, assessment errors in some cases reflected the legacy of this lawsuit but in other cases were unrelated. Associating data with the wrong AU, using data with unknown or limited data quality documentation, and applying BURP bioassessment methods to stream types they weren't designed for (ephemeral streams, lake outlets, beaver-influenced streams, etc.) all also contributed to assessment errors corrected during the study period.

It is perhaps not surprising that 2002-2022 trends were driven primarily by assessment progress. Considering 49% of stream km were unassessed but only 35% were impaired in 2002, there was greater potential for assessment progress than restoration at the beginning of the study period. In addition, although the CWA establishes a permit process, minimum wastewater treatment practices, and associated compliance enforcement mechanisms for point source discharges, nonpoint sources do not require a permit under the CWA. In Idaho, nonpoint sources are managed primarily through a voluntary adaptive management process. State statute [41] and Idaho's nonpoint source management plan [42] specify state and federal land management agencies responsible for identifying and implementing appropriate nonpoint source pollution control measures in Idaho. Idaho's nonpoint source management rules [43] envision a process where designated management agencies implement and iteratively modify nonpoint source pollution control practices as needed until water quality standards are achieved. Rules state that "violations of water quality standards which occur in spite of implementation of best management practices will not be subject to enforcement action" [44] and instead best management practices will be evaluated and modified as needed. Idaho rules also require that best management practices addressing agricultural nonpoint sources be adopted on a voluntary basis [45]. For some streams, the 20-year period examined in this study also may not have been sufficient for point or nonpoint source control efforts to achieve water quality standards.

To my knowledge, similar trend analyses have not been conducted in other states for comparison. The relative contribution of assessment progress and restoration may vary across states with differing water quality standards, monitoring and assessment approaches, resources, and pollution control approaches. Comparative analyses across states would likely be informative. Considering all state 305(b) data are now stored in a standardized national system (ATTAINS) [28], it may be possible to implement similar analyses in other states or at a national scale. Using ATTAINS data and methods described here, states or USEPA may be able calculate and report the percentage of stream km or AUs changing status due to assessment progress and restoration each IR cycle. This would enable states and EPA to document and track the relative contribution of these two drivers as state and federal water quality management efforts evolve. The CWA only requires states to report if water quality standards are attained, but summarizing status change reasons is relatively simple and can provide useful feedback on state CWA implementation efforts. In addition, identifying AUs changing from impaired to unimpaired because water quality improved creates a database of successfully stored waters for further analysis. Describing the characteristics of restored streams (watershed landcover, impairing pollutant(s), presence/absence of a TMDL and point source permits, restoration funding and actions, etc.) may help identify important predictors of restoration success. For example, comparing the statistical distribution of land use descriptors (percent forested area, road density, point source density, etc.) among restored waters to the distribution within the entire population of waters in a state may help develop a profile of waters with high potential for restoration success. Once relevant characteristics of waters have been described, it may be possible to use statistical methods such as classification tree analysis to identify factors most likely to cause waters to change from impaired to unimpaired due to water quality improvement.

There would certainly be challenges with such analyses. Processes for delineating AUs and using external data for assessments differ across states. Within some states, assessment methods, water quality standards, and AU delineation procedures have changed significantly over time and may affect patterns. These and other potential confounding factors would need to be considered. In addition, there is no national database or national data standard for documenting watershed restoration activities in the United States. Past efforts to build regional and national-scale stream restoration databases found limited and inconsistent project documentation across agencies that made evaluating restoration effectiveness difficult or impossible [46-50]. This would also likely be challenging in Idaho. DEQ and each other government entity funding restoration activities in Idaho imposes its own documentation requirements on grantees and maintains its own database of restoration actions. There is no central repository documenting all completed restoration actions. Therefore, it can be difficult to evaluate the net effect of multiple restoration actions on water quality or 305(b) data. Past efforts suggest that combining data across databases would be a significant challenge without a common data standard for documenting restoration activities [46]. To build and expand upon the analyses described here, these challenges would likely need to be addressed.

Conclusions

This study demonstrated a novel approach for evaluating 305(b) data. Idaho and most other states have historically used 305(b) data primarily to fulfill CWA reporting requirements.

However, systematically analyzing 305(b) data can also help evaluate relative contribution of assessment progress and restoration to achieving CWA administrative goals. Analyses revealed that Idaho CWA progress 2002-2022 was driven primarily by assessment progress rather than water quality improvement, and assessment errors were common. Improving monitoring and assessment, especially stressor identification methods, may help prevent assessment errors in the future. At the start of the study period, more stream km had potential for assessment than restoration (49% unassessed, 35% impaired), but as of 2022 more have potential for restoration (39% impaired, 29% unassessed). Therefore, restoration success rates will likely become an increasingly important driver of 305(b) temporal trends in the future. This study identified AUs fully restored due to water quality improvement. Analyzing characteristics of restored waters may help develop a profile of streams with a high probability of restoration success. This analysis defined restoration as occurring when an AU changes from impaired to unimpaired due to water quality improvement, consistent with the CWA. Partial restoration also occurs when a pollutant no longer impairs beneficial uses within an AU, but the AU remains impaired by one or more other pollutants. Systematically analyzing characteristics of partially restored AUs may also yield useful information. Analyses focused on the state spatial scale, but the same methods could be used at smaller (basin and subbasin) spatial scales (see supporting information). Previously, interviews and surveys of state and federal staff implementing the CWA have been used to develop recommendations for accelerating CWA progress [51]. Novel analysis of IR data also holds potential to develop new empirically driven strategies and merits further investigation.

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Supporting Information

All data and R code used for analyses, Idaho IR documents 2002-2022, government reports cited in references, and supporting files are available through Open Science Framework at: https://osf.io/z4s89/?view_only=cb3730222db94b5696d994a97345fea8. Supporting files include a description of data compilation methods (S1) and 305(b) temporal trend plots at the basin and subbasin scale (S2).

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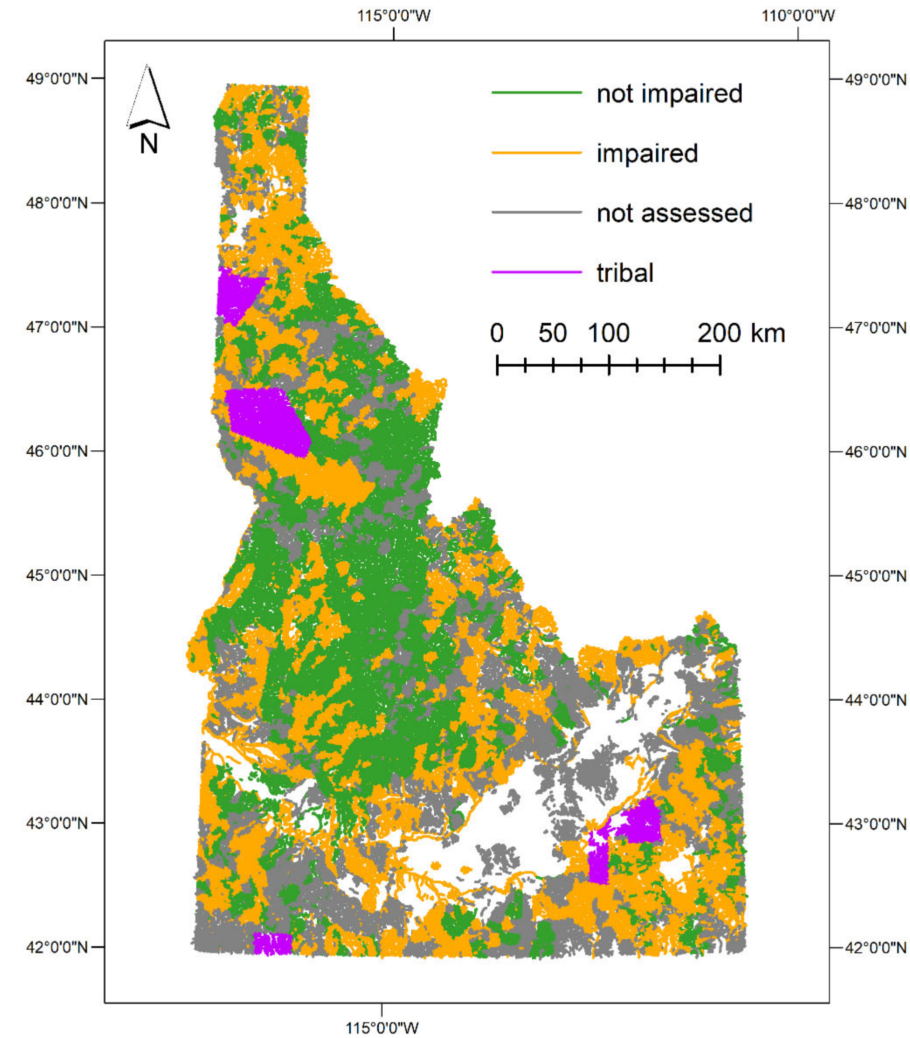
Figure 1


115°0'0"W
110°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
N
not impaired
impaired
not assessed
tribal
0 50 100 200 km
115°0'0"W

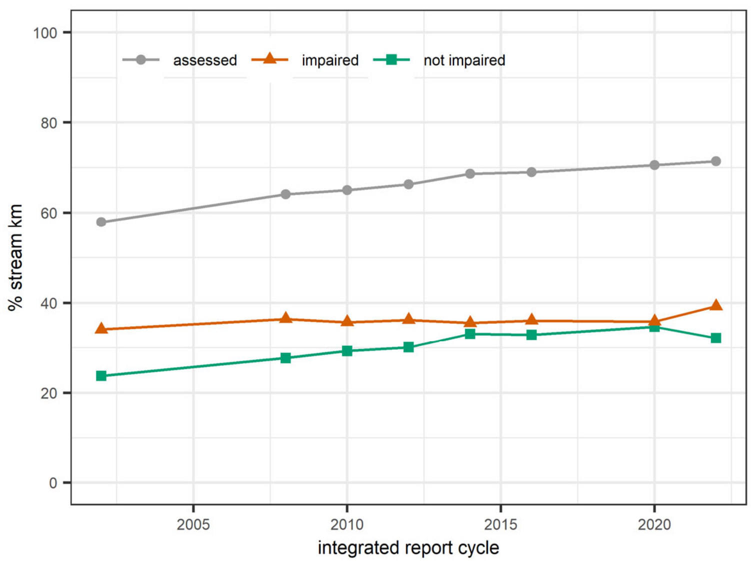

100
80
60
40
20
0
assessed
impaired
not impaired
% stream km
2005
2010
2015
2020
integrated report cycle

Figure 2