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) temporal trends. This analysis demonstrates how systematically analyzing 305(b) data in 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 progress assessing unassessed waters and correcting assessment errors. Restoration was defined as changes from not achieving to achieving assessed standards because water quality improved. From 2002-2022, the percent Idaho stream kilometers achieving 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 ≤ 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. In addition, the CWA requires a permit for point source discharges and dredge and fill material discharges to surface water; identification of maximum pollutant inputs that can occur while still meeting state water quality standards (total maximum daily loads, TMDLs) for impaired waters; state programs to address nonpoint source pollution; and state antidegradation policies for maintaining water quality in waters where standards are achieved, among other components. Together, these CWA requirements are intended to achieve water quality standards and thereby protect beneficial uses of water.

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. In addition, section 314 requires "an identification and classification according to eutrophic condition of all publicly owned lakes" to be included in state 305(b) reports, and CWA section 303(d) requires states identify and develop priority rankings for impaired waters that require a TMDL. 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 a TMDL (§ 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. Because states do not have sufficient resources to monitor and assess all state waters and all applicable water quality standards every two years, each state 305(b) report typically includes updated assessment information 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 percent 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. State 305(b) data document progress towards achieving CWA administrative goals, and ultimately determine requirements for TMDLs, point source discharge permits, and many other CWA provisions contingent on standards attainment. 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. Therefore, to develop strategies to increase the proportion of waters achieving applicable standards, states need to identify 305(b) data trends and associated drivers.

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 percent 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 prior 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) were compiled to evaluate progress towards CWA goals for Idaho streams. Analyses focused on streams because, as of 2022, the Idaho Department of Environmental Quality (DEQ) had assessed 71% of the state's >148,000 stream km using relatively consistent methods since 2002 [14,15] (Fig 1). State-scale temporal trends for percent lake surface area impaired would be strongly biased by the relatively few large lakes and reservoirs that comprise most of state lentic surface area and are the primary focus of monitoring efforts. Out of 641 lentic systems in the state, the 47 that exceed 4 km^2 surface area represent 90% of total state lentic surface area.

Fig 1. Idaho river and stream status in Idaho's 2022 Integrated Report.

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) [16]. Idaho's streams are divided into 5,908 AUs [17]. AUs were delineated primarily based on stream order [18,19], 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 [14,15] and methods described in IR documents. DEQ managed and reported IR data using

Microsoft Excel for the 2002 IR, using USEPA's Assessment Database (ADB) software [20] for 2008-2016 IRs, and using EPA's cloud-based Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS) software [21] 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 that were either collected by DEQ, submitted by external entities for the IR through a public call for data, or were otherwise publicly readily available, to assess support of beneficial uses. A data quality screening process was used to determine if external data had sufficient rigor and documentation to be used in the assessment process [14,15]. Generally, DEQ's assessment process was to i) identify beneficial uses of water requiring protection for an AU based on Idaho water quality standards [22], ii) compare any available water chemistry data to applicable water quality standards, and iii) and if available within the AU, use macroinvertebrate, fish, and habitat data collected through DEQ's Beneficial Use Reconnaissance Program (BURP) bioassessment program to assess support of cold water aquatic life beneficial use. Using a targeted non-random monitoring design, DEQ collected BURP data in over 200 wadable 1st-4th order stream reaches throughout Idaho each year in most years since 1993 [23,24]. 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 [14,15] 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 [25]. 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, Idaho has assessed AUs entirely within federally designated Wilderness or certain roadless area categories defined in federal roadless rules with no readily available monitoring data as unimpaired, presuming all beneficial uses are supported due to limited anthropogenic watershed disturbances. Across the 2002-2022 IRs, 4.3-6.7% of stream km were placed in Category 1.

CWA Progress Temporal Trends

CWA progress temporal trends were evaluated by calculating the percent 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 percent km by status prior to implementation of the tribal waters policy (2002-2016 IRs) and were excluded for calculations after implementation of the tribal waters policy (2018/2020 IRs) 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 percent stream km within each 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. For example, 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 percent stream km changing from impaired to unimpaired for each reason was calculated for each IR cycle.

Results and Discussion

From 2002-2022, the percent of Idaho stream km assessed increased from 59% to 71% (Fig 2). Concurrently, the percent impaired km increased from 35% to 39%, and the percent unimpaired km increased from 24% to 32% (Fig 2). Because calculated percent km impaired and unimpaired were based on targeted nonrandom monitoring, these percentages likely are not representative of the entire population of state streams. A comprehensive and unbiased estimate of the percent 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 of percent stream km in EPA-defined ‘good’, ‘fair’, or ‘poor’ condition classes at the regional and national scale [26]. During 2013 and 2015, DEQ’s Idaho Wadable Streams Survey collected BURP data using a probabilistic design to estimate the precent of state 1st-4th order wadable stream km supporting cold water aquatic life use (71.2% supporting, 28.8% not supporting) [25]. 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, whereas 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. Percent Idaho stream km assessed, impaired, and not impaired.

Table 1. Percent 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	restored 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

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). The percent stream km changing due to assessment progress was at least 3 times greater than percent km changing from impaired to unimpaired each cycle. In addition, the observed increase in percent unimpaired stream km appears 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 1). 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. In response to citizen lawsuits related to limited USEPA implementation of the CWA's TMDL program, in 2000 the U.S. Congress commissioned a National Research Council (NRC) evaluation of the scientific basis for CWA assessment and TMDL processes [27]. The NRC report 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) because "many waters now on state 303d lists were placed there without the benefit of adequate water quality standards, data, or waterbody assessment" [27]. USEPA did not implement this recommendation; USEPA IR guidance does not allow states to develop a preliminary list [4,28]. In Idaho, citizens groups successfully sued USEPA for approving Idaho's 1992 303(d) list because it did not adequately consider all readily available water quality data [29]. 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 from 62 to 962 and established a timeline for developing TMDLs for these waters [29, 30]. 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, or in some cases based on qualitative assessments or public desire to maintain existing water quality for certain waters [30]. Based on delisting documentation reviewed for restored waters, the legacy of this lawsuit, plus unrelated assessment errors such as associating data with the wrong AU, using data with unknown or limited QA/QC documentation, and applying BURP bioassessment methods to stream types they weren't designed for (ephemeral streams, lake outlets, beaver-influenced streams, etc.), all contributed to assessment errors corrected 2002-2022.

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 and are managed primarily through a voluntary adaptive management process in Idaho. State statute [31] and Idaho's nonpoint source management plan [32] 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 [33] 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" [34] and instead best management practices will be evaluated and modified as needed. Idaho rules also require best management practices addressing agricultural nonpoint sources be adopted on a voluntary basis [35]. 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) [21], it may be possible to implement similar analyses in other states or at a national scale.

Conclusions

This study demonstrated a novel approach for evaluating 305(b) data. Analyses revealed that Idaho CWA progress 2002-2022 was driven primarily by assessment progress rather than water quality improvement, and assessment errors were common. Analyses focused on the state spatial scale, but the same methods could be used at smaller (basin and subbasin) spatial scales (see supporting information). Results suggest potential strategies for accelerating CWA progress in Idaho. 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 restored due to water quality improvement. Describing the characteristics of these streams (watershed landcover, impairing pollutant(s), presence/absence of a TMDL and point source permits, restoration funding and actions, etc.) may develop a profile of streams with a high probability or 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. Previously, interviews and surveys of state and federal staff implementing the CWA have been used to develop recommendations for accelerating CWA progress [36]. 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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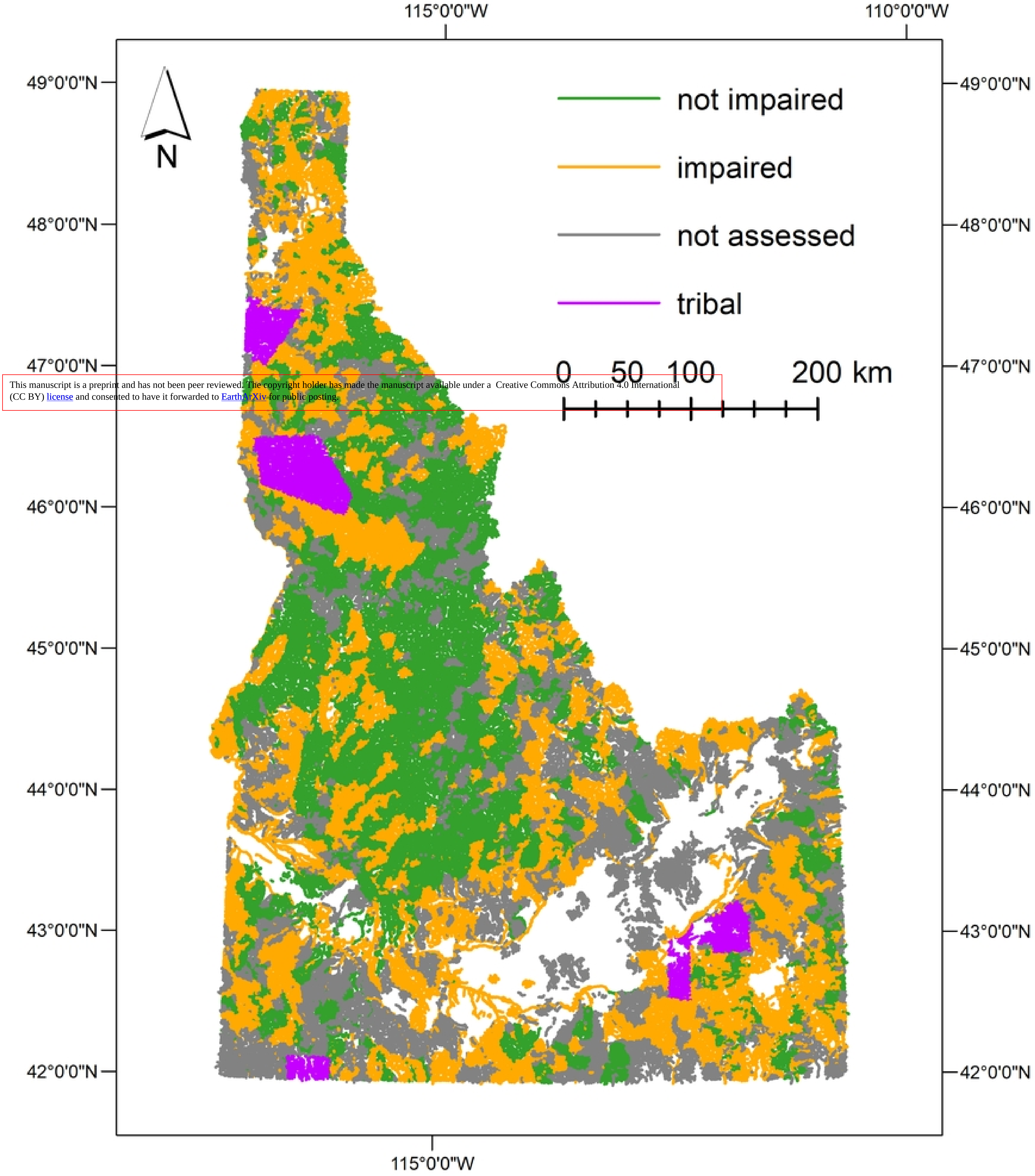
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Figure1

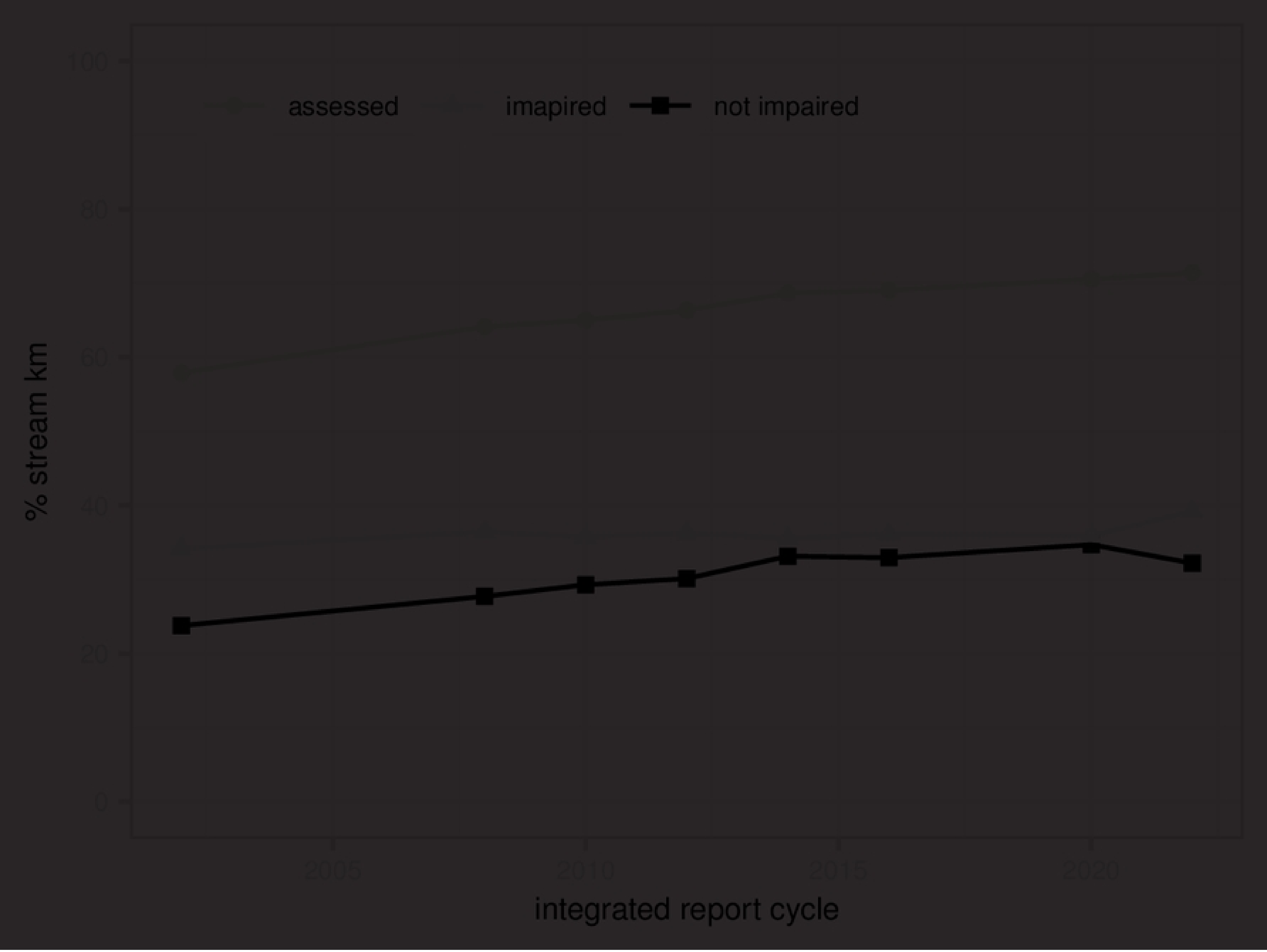
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Figure2