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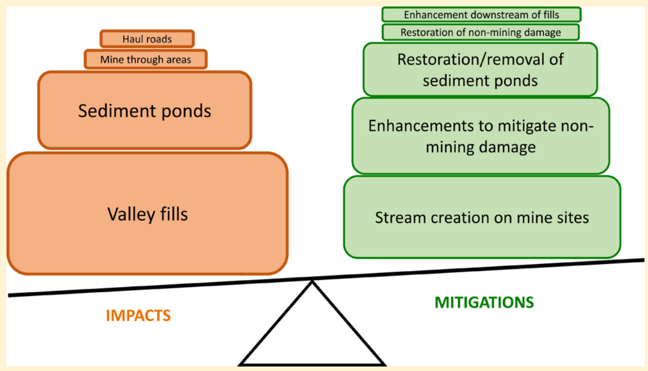
Restoration As Mitigation: Analysis of Stream Mitigation for Coal Mining Impacts in Southern Appalachia

Margaret A. Palmer* and Kelly L. Hondula

National Socio-Environmental Synthesis Center and Department of Entomology, University of Maryland, College Park, Maryland 27042, United States

Supporting Information

ABSTRACT: Compensatory mitigation is commonly used to replace aquatic natural resources being lost or degraded but little is known about the success of stream mitigation. This article presents a synthesis of information about 434 stream mitigation projects from 117 permits for surface mining in Appalachia. Data from annual monitoring reports indicate that the ratio of lengths of stream impacted to lengths of stream mitigation projects were <1 for many projects, and most mitigation was implemented on perennial streams while most impacts were to ephemeral and intermittent streams. Regulatory requirements for assessing project outcome were minimal; visual assessments were the most common and 97% of the projects reported suboptimal or marginal habitat even after 5 years of monitoring. Less than a third of the projects provided biotic or chemical data; most of these were impaired with biotic indices below state standards and stream conductivity exceeding federal water quality criteria. Levels of selenium known to impair aquatic life were reported in 7 of the 11 projects that provided Se data. Overall, the data show that mitigation efforts being implemented in southern Appalachia for coal mining are not meeting the objectives of the Clean Water Act to replace lost or degraded streams ecosystems and their functions.



INTRODUCTION

Streams and rivers are among the most threatened ecosystem types on earth and the most vulnerable are the smallest tributaries—the headwaters—which can have ephemeral, intermittent, or perennial surface flows.[1,2] This vulnerability is particularly conspicuous in the coal mining regions of the Appalachians, U.S. where surface mining has impacted hundreds of headwater streams.[3,4] In fact, surface mining and mine reclamation activities are the dominant drivers of land-use change in the central Appalachians.[5]

The surface mining process begins with the removal of vegetation, soil, and rock that lay overtop of coal seams. The exposed seam is then fractured; the coal is extracted and eventually transported for further processing. Some surface mining operations store the soil and rock material (overburden) and use part of it later during postmining reclamation[6] but because the unconsolidated material has a substantially increased volume, excess overburden is stored in valley fills. These fills and many other activities associated with large-scale surface mining degrade nearby streams and often result in the complete loss of headwater streams as well as the contamination of waterways by alkaline mine drainage.[7] Loss of aquatic biodiversity below the mining operations is well documented[8−10] and there is no evidence that these downstream impacts decline over time—mine sites reclaimed over 20 years ago still contribute to significant degradation of water quality.[11]

Agencies are required by law to avoid, minimize, and mitigate impacts from fill activities so that no significant loss of ecological values occurs from past, present, and foreseeable future impacts. The U.S. Army Corps of Engineers (Corps) is charged with reviewing mining permit applications that will impact jurisdictional waters and they have relied heavily on compensatory mitigation to meet this mandate. While regulations and assessment methodologies for mitigation requirements have changed over time, these basic requirements—avoid, minimize, mitigate—remain. Unavoidable loss of stream structure and function must be compensated for by restoring, recreating, or preserving other waters; functions are defined as chemical, physical, and biological processes.[12] Under section 404 of the Clean Water Act (CWA), the Corps must approve proposed compensatory mitigation plans, and ensure mitigation is completed successfully.

The most recent regulation describing the requirements for compensatory mitigation was published in 2008[13] (33 CFR Part 332). The regulation defines mitigation as "restoration, establishment (creation), enhancement or preservation of

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aquatic resources" (§332.2). While studies on implementation, monitoring, and outcomes of nonmitigation related stream restoration projects are increasingly common,[14−16] the extent to which mitigation projects for surface mining result in recovery of lost aquatic resource functions is largely unknown. Most evaluations of stream mitigation projects on mine sites that are available have been done by the permittee and are generally limited to visual structural measures.

Stream restoration science today emphasizes actions that positively influence the hydrogeomorphic and ecological status of a degraded stream such that it is similar to a healthier nearby "reference" stream.[17,18] Projects that are focused on recovering the types of attributes required by the CWA (chemical, physical, and biological functions) take measurements to assess water quality, discharge dynamics, and biological composition.[19,20] To fill the void in information on the effectiveness of restoration projects conducted to mitigate for mining impacts, data were gathered from publicly available annual monitoring reports done by permittees and submitted to the Corps to meet requirements set when the mines are permitted. Given recent science documenting extensive impacts to streams below mine sites, particularly large-scale surface mine sites,[3,9,11] this analysis focuses on the south central Appalachian coal mining region.

Coal is found in Appalachia stretching from northern Alabama to northeastern Pennsylvania. In the south central Appalachian ecoregions extensive seams of bituminous coal have been mined since the 1800s.[21] Surface mining has been extensive and the most destructive form, mountaintop mining, increased in prevalence in this region in the 1990s. These and other large-scale mining projects, including mining through streams, are permitted by the Corps under the assumption there is no significant environmental damage because impacts are mitigated for.[12]

The goal of this study was to explore the chemical, physical, and biological outcomes of restoration projects being implemented to compensate for the impacts of mining and ask if there is scientific evidence that mitigation projects are successful in meeting the objectives of current compensatory mitigation regulations and, more broadly, the objectives of the CWA. Based on information from monitoring reports submitted to the Corps for more than 400 mitigation projects in the Appalachian region, this article addresses: (1) what types of restoration actions have been undertaken to mitigate for impacts to streams and do these actions vary with the amount of mining impact? (2) What were the required assessment criteria? (3) What conclusions about project outcomes were reached and are they supported by data provided in the reports? (4) Is there evidence that mitigation projects are meeting the objectives of the CWA?

■ MATERIALS AND METHODS

Publicly available monitoring reports for 434 stream mitigation projects associated with individual permits for surface coal mining in West Virginia, Kentucky, Tennessee, and Virginia were obtained by weekly requests between December 2008 and January 2014 to four Corps district offices: Huntington WV, Louisville KY, Norfolk VA, and Nashville TN. Monitoring reports are typically required on an annual basis for each of five years postmitigation unless the project is not performing at the required level in which case additional years of monitoring are required. At the end of the required monitoring period, a site visit is typically conducted by a Corps officer to confirm the status of the mitigation and to authorize release from any further monitoring requirements.

When it issues a fill permit, the Corps measures and defines the total amount of stream impacts and then calculates the required amount of stream mitigation to offset the impacts associated with each permit based on Corps protocols. The amount of mitigation required relative to the permitted impacts is the mitigation ratio. While the CWA requires a full replacement of lost aquatic resources and functions, it does not define what metrics should be used for assessing resources or functions. So, in order to calculate the mitigation necessary for a given amount of impacts, the Corps measures impacts and mitigation in terms of units that are comparable across sites: either stream length or "functional units" based on one of several ecological indices. For example, under the Eastern Kentucky Stream Assessment Protocol, Ecological Integrity Units are calculated as the product of the stream length and a scaling factor to describe the quality of the stream based on a combination of visual habitat assessments, conductivity measurements, and a macroinvertebrate index.[22] In approving §404 fill permits, the district Corps offices are responsible for reviewing and ensuring the accuracy of information, including stream type and quality, reported by permit applicants.

Database Creation. For each mining permit with associated mitigation monitoring reports, information was recorded pertaining to the amount of impacts mine companies were required to mitigate for including impacts from valley fills, sediment ponds, haul roads, drainage corridors, and mine-through areas; categorization of the types of streams being impacted and the nature of those impacts (typically called "permanent" if buried by a fill, "temporary" for other impacts); the performance criteria used to determine project success; and monitoring data from the annual monitoring reports. All information was placed in a relational database created using R version 3.0.2; original documents, raw data, and analysis methods are available online at http://doi.org/10.5061/dryad.2d504 as is a Google Earth layer of monitoring site locations (Supporting Information (SI), Section S1).

Mitigation projects were considered distinct if they had individual monitoring data, were described with a different stream classification (ephemeral, intermittent, or perennial), or were characterized in reports as a separate activity or construction project. For projects in which multiple monitoring sites along the stream were evaluated, data were averaged to determine a final score; however, most projects had only one monitoring site.

Projects were categorized for this analysis as restoration, enhancement, or creation based on the nature of activities performed for mitigation as they were described in reports. Projects that were interchangeably referred to as enhancements and restorations were distinguished by categorizing them as restoration if they involved major earth-moving activities on existing channels such as natural channel design reconfiguration of channel form and regrading banks; and as enhancements if they involved placement of in-stream wood or rock structures and/or replanting of riparian vegetation but no major realignment of the channel. Creations were projects in which an entirely new stream channel on the mine site was excavated, or an existing drain or diversion ditch built during the mining process to route water off the site was considered a newly formed stream for mitigation purposes.

Mitigation Outcomes. For each mitigation project and monitoring report year, performance criteria required by the

Corps as well as monitoring data were documented, including all subjective, objective, qualitative, and quantitative information in the reports. Most projects had multiple performance criteria including for example achieving at least "suboptimal" habitat assessment according to the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocol (RBP) in the mitigation stream. Habitat assessment values generated using the RBP are hereafter referred to as HAV scores. When conflicting information was presented in reports, such as discrepancies between field sheets and data summaries, whichever data showed less ecological impairment was used for data analyses.

Ecological outcomes were assessed for projects that were at least three years into their monitoring periods. Since "improved" HAV scores over time was the most common requirement to meet regulatory compliance, HAV scores[23] from the first year of monitoring available were compared to the most recently reported score. Also analyzed were how many projects were reported in each "status" category according to the assessment metrics, for example, "poor" (<60), "marginal" (61−112), "suboptimal" (113−165), "optimal" (166−200) for HAV scores and impaired vs unimpaired status according to accepted biological indices used for stream health assessments by state agencies such as the West Virginia Stream Condition Index (WVSCI score).[24]

For projects that provided biological or water quality data, evidence of chemical and biological improvement over time was assessed by comparing the baseline or first year monitoring data to the most recently reported values. Measurements were also compared to levels beyond which regulators have established thresholds for impairment to aquatic life (conductivity, 300 μS/cm,[25] sulfate 50 mg/L[26]); or, levels that exceed the EPA freshwater chronic criterion concentration (selenium, 5 μg/L[27]).

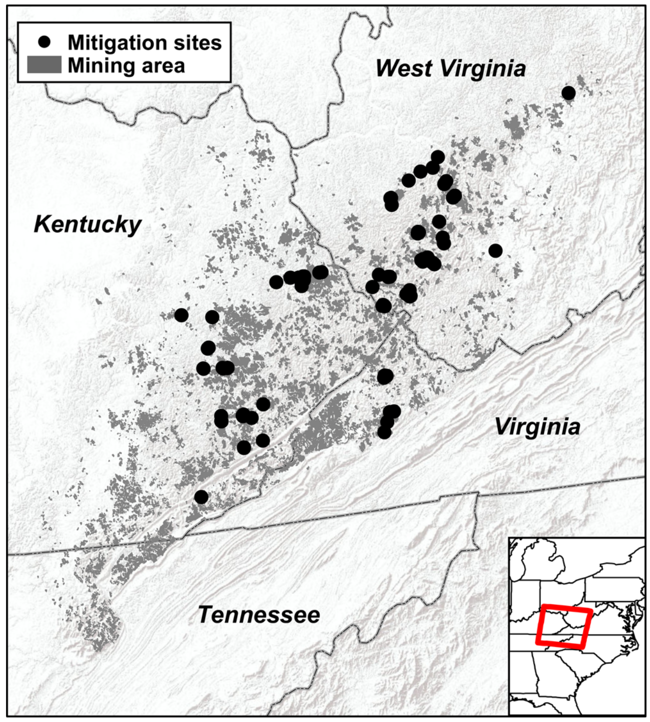

Figure 1. Location of the 100 mitigation project sites ≥3 years into monitoring. Dark gray area is the extent of mountaintop mining in Appalachia from Geredien.[56]

RESULTS AND DISCUSSION

Information was available on 434 planned mitigation projects associated with 117 permits for surface mining. Of these, 286 of the projects were constructed; 78 of these were in WV, 163 in KY, 28 in TN, and 17 in VA. Of the 286 projects that had begun, 100 were at least 3 years into their monitoring periods (Figure 1).

Along with three in-lieu fees paid to mitigation banks,the 434 projects were associated with 578 689 feet of planned stream mitigation; at the time of writing, construction was completed for 485 445 feet of these (SI Figure S1). Of this length of completed mitigations, 44% was in perennial streams and 34% in intermittent or ephemeral channel even though only 5% of the impacted streams were classified as perennial and 59% as intermittent or ephemeral. A large fractions of the impacted and mitigated lengths (35% and 22%, respectively) were not classified with respect to flow status. At least 360 000 feet (62%) of the impacts were permanent impacts (i.e., covered by overburden in fills), only 3% of which were impacts to perennial streams.

The finding that mitigation was mostly focused on perennial streams while the impacts were primarily to ephemeral and intermittent streams is inconsistent with the 2008 Compensatory Mitigation Rule[13] (page 19675, §e(2)) that mitigation should be of a similar type to the affected aquatic resources. This bias toward perennial streams has been allowed because the methods for calculating required mitigation "units" (SI Section 2) do not distinguish between ephemeral, intermittent, and perennial streams i.e., the assumption is that they are equivalent. The exception is the now-discontinued Stream Habitat Unit (SHU) method (SI Section 2.5) in which the mitigation value for a perennial stream exceeds that for an intermittent/ephemeral stream.

This bias toward perennial streams is despite the absence of scientific evidence that the values and functions of perennial streams exceed those of streams not flowing year-round. The latter are known to play unique and important roles in river networks from both hydrological and ecological standpoints.[1,28] Additionally, recent studies in the coal mining regions of southern Appalachia showing that structure and function, including for example habitat, invertebrate composition, rates of decomposition and retention of organic matter, differ between natural intermittent and restored or created perennial streams[29,30] indicate that a bias toward using perennial stream restoration to make up for intermittent losses does not compensate for those losses. This lack of compensation, and the growing scientific evidence of their ecological and hydrological importance,[31] indicate that in addition to the major impact that surface mining has on diverse terrestrial ecosystems in Appalachia, it also results in a net loss of small streams and their associated functions.

There was sufficient information to compare the total length of impacted vs mitigated streams for 57 of the 117 permits. There was a significant inverse relationship (p = 0.01612) between the total length of streams impacted by those permits and the relative length of stream mitigation, that is, larger projects had lower mitigation ratios on the basis of stream length (Figure 2). These permitted projects assume a fungibility between quantity and quality, by planning to replace longer lengths of streams evaluated as lower quality with shorter segments of higher quality stream, as determined using

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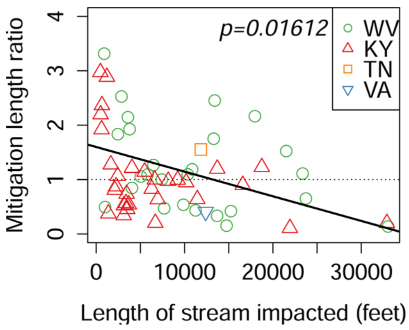

Figure 2. Comparison of stream length mitigation ratios. Each point represents a permit decision. Mitigation ratio is calculated as the cumulative length of stream mitigation segments divided by the total length of streams permitted to be impacted under one permit. Dotted line indicates ratio = 1.

a mitigation metric (e.g., "ecological integrity units", SI Section 2).

Use of these metric calculators to determine mitigation requirements indicates that the Corps accepts them as adequate to assess stream functions. Yet the calculators (SI Section 2) do not require direct measurement of functions that represent key processes; even for the simplest process—discharge over time. Further, the calculators incorporate a number of simplifying assumptions not supported by any scientific evidence, which allow for deterioration of one type of ecological function to be replaced by another. For example, under the Eastern Kentucky Stream Assessment Protocol (EKSAP), planned improvements in habitat quality can compensate for deterioration in macroinvertebrate communities or for degradation of water quality yet there are no scientific studies that would support this substitution. Further, the lowest possible subindex scores for conductivity and habitat quality under EKSAP are at 500 μS/cm and a HAV score of 100 ("marginal"); however, there is no credit penalty for further deterioration beyond these conditions, even though many mitigation projects reported far worse conditions. Finally, when evaluated only on the basis of stream length, steep ditches constructed on the edges of valley fills and lined with rip-rap may be considered equivalent to the buried forested headwater streams despite presumably dramatic differences in ecological functions such as the downstream delivery and processing of organic matter, hydrologic variability, temperature moderation, and nutrient cycling.

Type of Mitigation. On-site mitigation projects included (1) "restoration", "re-establishment", or "re-creation" of stream channels that were filled by mining sediment ponds at the base of valley fills (N = 36); (2) "creation" or "establishment" of new stream channels in mining sediment ditches on the perimeter of flattened and deforested mountaintops or in drainage corridors at the side of valley fills (N = 16); and (3) "enhancements" to the in-stream or riparian habitat of stream channels downstream of valley fills (N = 48) (Figure S2, SI; Figure 3).

The restoration projects in the mitigation database typically followed the "Natural Channel Design" (NCD) approach[32] which focuses on channel form and enhancement of in-stream habitat features. This approach has been heavily criticized from a hydrologic and geomorphic perspective[16] and it has not been shown to restore ecological function.[33−35] Indeed, numerous studies have shown that such form-based approaches fail to improve stream biodiversity.[36] The NCD approach to

Figure 3. Photos from monitoring reports showing restoration projects. "Stream D" (top left) a created channel; "Upper Curry Branch" (bottom left); "Coal Hollow" (bottom right) a restored channel next to a highway; "Harpes Creek" (top right) a created channel.

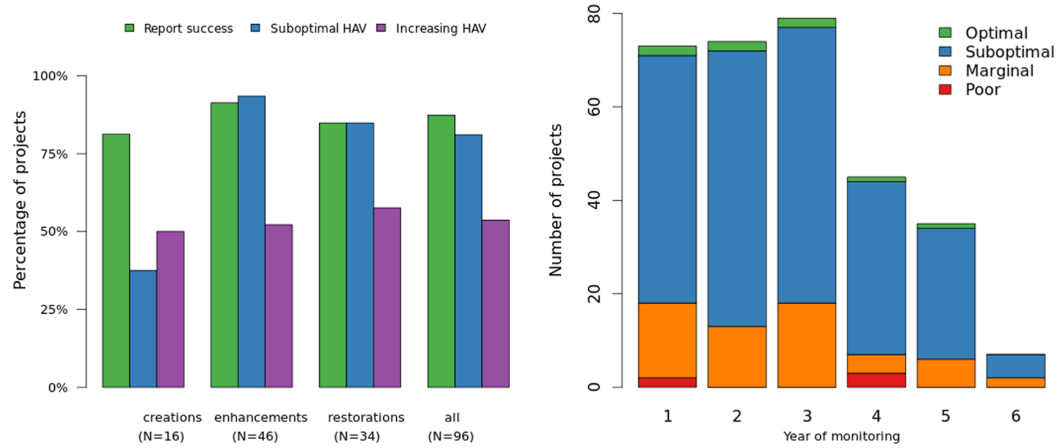

Figure 4. (a) The percentages of total projects with 3 or more years of monitoring data that also have HAV scores (N = 96) that are described as "meeting goals", having at least suboptimal habitat (typically, HAV >113) or showing an increasing habitat score. (b) Habitat score for mitigation projects by year postimplementation. The categories in the legend are based on the habitat classification scheme most commonly used in reports (e.g., HAV <113 are marginal or poor).

restoration was not developed to address ecological function and the method[37] does not involve measuring ecological processes or biota as part of the design. Despite these shortfalls and the fact that regulations require full replacement of all lost aquatic resources and functions, the NCD method remains the primary approach even for plans approved by the Corps since the implementation of the 2008 rule. Mitigation plans assume that habitat improvements alone will eventually lead to the recovery of biotic communities despite evidence to the contrary.[17]

There have only been a few studies that include an assessment of the effectiveness of stream creation. One of these examined two projects in North Carolina (U.S.) and based success on whether or not projects met regulatory success criteria at the time of construction; both met regulatory requirements however authors were not able to evaluate ecological status with such a small sample size.[38] Another study evaluated five creation projects on reclaimed mine land in WV and concluded that using ecological standards, created streams on mine land do not mimic natural streams.[39] A third study reported that created streams do not produce biological outcomes comparable to unimpacted reference streams.[29] Similar conclusions of inadequacy have been reached for channels constructed in other geographical regions.[40,41] Currently, there are no scientifically validated methods for constructing a stream in an area that did not formerly have one and the feasibility of doing this has been challenged by the scientific community[42,43] and the Corps and EPA who discourage stream creation in the 2008 rule ([13], page 19 596).

Of the monitoring reports reviewed, off-site mitigation projects (N = 24) were typically "enhancements" that varied from reconfiguration of streams using NCD principles[32] to removing debris along stream corridors (Figure 3). The most frequently used enhancement methods were the installation of in-stream structures such as root wads and cross vanes, and planting or re-establishment of disturbed riparian vegetation, which were used in 86% and 70% of enhancement projects, respectively. Efforts to stabilize banks were used in only 23% of the enhancement projects; some projects simply removed debris or did not report what was done.

Assessment Criteria. Performance standards for mitigation projects were primarily related to physical habitat parameters. While reporting of biological or chemical data was required for some projects, they did not routinely have to meet any biological or chemical standards. The most basic form of stream monitoring—discharge over time—was not required in the permits. Monitoring and compliance requirements for compensatory mitigation are set by federal and state regulatory agencies and can vary by region and by project within a region.[43] Most of the projects reviewed had to report annually on several performance criteria specified in the permit conditions; however, for three permits, the reporting documents explicitly stated that the permit holder was only asked to document completed construction of planned restoration projects. The most common performance criteria were related to meeting a minimum standard for physical parameters associated with stream morphology such as "Rosgen stream classification as predicted" or "riparian zone with a variety of species alive and healthy," or to show improvement in habitat quality (SI Table S1).

The second most common requirement was either meeting a "suboptimal" HAV score, increasing the HAV, or showing an improvement in one of the metrics used to assess stream status for mitigation purposes, for example, the total number of ecological integrity units as determined by EKSAP.[22] As an assessment parameter, habitat quality is not unusual; however, there is substantial scientific evidence that while it may be important to measure it is not sufficient for assessing ecological outcome[44] and is not an adequate surrogate for biological assessments.[45] Habitat is not a reflection of ecological function[36,46] which the CWA explicitly defines as "physical, chemical, and biological processes" (33 CFR 332.2; 40 CFR 230.92). The EPA RBP describes "suboptimal" habitat quality as streams having "40−70% of the necessary structure to sustain a viable macroinvertebrate population."[23]

Fewer than a third of the projects were required to collect and report biological or chemical data, and only eight projects had criteria requiring an improvement in biotic indices or meeting an unimpaired score on state level biological criteria such as the WVSCI.[24] Thus, overall, the assessment requirements of the mining projects are very minimal and this is true whether in comparison to the monitoring protocols of restoration projects that are routinely recommended and used by scientists (e.g.,[47,48]) or those recommended by federal

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agencies.[49] Even the mitigation assessment protocols recommended specifically for high gradient streams in eastern Kentucky and western West Virginia[50,51] were not applied to most of the mitigation projects reviewed.

Mitigation Outcomes. Although some projects reported modest gains in habitat quality over the duration of the monitoring period, there was no evidence of improvement in biotic indices or abatement of water quality degradation due to restoration actions. Despite the minimal performance standards required by permitters, a large fraction of the projects still failed to meet requirements. One hundred projects were at least three years into their monitoring periods, which allowed for evaluation of project outcomes. Most reports did not discuss the relationship between data gathered in the field and the project outcome; seventy-nine of the projects (80%) were described in the report narratives as successful or "likely to be successful"; only four were described as not meeting goals or unlikely to meet them (Figure 4a). The others were described as needing more time to meet performance standards or no qualitative assessment was provided in the report regarding the success or failure of the project.

Across all mitigation projects, 96 reported habitat quality into at least the third year of monitoring; of these, 76 reported at least a "suboptimal" (>113 out of 200) HAV score, but only 51 of those 96 reported equal or higher HAV scores than first reported (Figure 4a). Consequently, projects with "poor" (<60 out of 200) HAV scores as well as those which showed declining habitat quality throughout their monitoring periods could be meeting their respective regulatory standards. The most common reason for higher scores was improvement in the category of "vegetation protection" or "riparian width" (SI Table S2).

Thirty-six projects in the database had been monitored for at least five years, typically the minimum monitoring time required for the permits. Of these, 23 required further monitoring for not having met regulatory performance criteria. Most were described as "progressing" toward success and likely to meet their goals given time; however, two stream creation projects were described as unlikely to meet their goals and were developing "adaptive management plans". Eleven projects requested release from monitoring by claiming to have met performance criteria as outlined in the permit. Two stream creation projects were being carried out under a permit that was suspended due to noncompliance and a court ruling.

With respect to the most commonly reported criteria (HAV scores), the stream creation projects had the lowest scores and consistently were ranked as "marginal" or "poor" (mean HAV score = 89.4, N = 16; SI Table S3). Only half showed improvement whereas five others decreased in quality and the other three were only scored once due to lack of water flow in the channels. Enhancement (N = 46) and restoration (N = 34) projects scored higher than creations (mean = 137.6 and 138.3, respectively) and while some of the projects (52% and 58%) showed improved HAV scores over time, the majority (97%) of all projects remained in the suboptimal or marginal score categories even after five years (Figure 4b). This was somewhat surprising since habitat is the factor most often directly manipulated by mitigation actions, yet is consistent with results from a small field study that found habitat was not significantly improved in Appalachian streams restored or created to meet to meet coal mining mitigation requirements.[52]

In addition to the short-comings with respect to habitat, most of the streams for which mitigation reports provided biotic or chemical data were scored as biologically impaired according to state standards and reported levels of water quality parameters exceeding state and federal criteria. Most of the projects that provided biological data were from West Virginia and used the WVSCI for macroinvertebrate assessments. Across these projects (N = 27), there was no statistically significant increase in WVSCI scores from the first to the most recently monitoring report (Figure 5a). Only two of these projects were required to show biological improvements to meet permit performance criteria. Sixteen projects in Kentucky provided biological data using the Macroinvertebrate Biotic Index (MBI[53]) and these also showed no improvement over time (Figure 5b). Across all projects that reported biological data, creation projects had decreasing scores over time as did most of the restoration projects (SI Table S3). For the two WV stream creation projects reporting biological data, the WVSCI scores fell during the monitoring period from "unimpaired" status to "impaired" status.

Chemical data on water quality was provided for 56 of the 100 mitigation projects for which reports were available. Water quality data were typically reported as concentrations without discharge data, making it difficult to compare trends across years. However, compared to concentrations conducive to aquatic life, many of the measurements were elevated (Figure 5). For specific conductivity, 43 projects reported conductivity above the EPA aquatic life benchmark (300 μS/cm^2)[25] (Figure 5c) and for sulfate, values were often well above the 50 mg/L threshold reported by Bernhardt et al.[26] (Figure 5d). Levels of selenium that can impair aquatic life (>5 μg/L)[27] were reported for 7 of the 11 projects that included Se data; the average most recently reported Se value was 11.25 μg/L (n = 11; Figure 5e). Conductivity in mitigation streams in watersheds with mountaintop mining was significantly higher than in mitigation streams impacted by other types of mining or nonmining related disturbances. Water quality was rarely a determinant of compliance even though these data indicate that projects acceptable as mitigation had water quality that was often impaired (Figure 5). This could be due to several reasons. First, few projects had to collect chemical data and even fewer (8) were required to show improvement over time or meet some standard (Table S1, SI).

Second, when water quality parameters such as conductivity is part of a mitigation metric (e.g., EKSAP, SI Section 2.1), it is only one component of the calculation for the stream quality index and can therefore be substituted by planned improvements to habitat or biota. However, given the conductivity levels reported, biological impairment is certain for many of the mitigation projects[3,9,54] as indicated by the number of impaired WVSCI and EKSAP MBI scores (Figure 5; SITable S4).

Despite biological and chemical evidence of impaired stream status for many of the mitigation projects and the overwhelming number that have "suboptimal" or worse habitat, 80% of the projects were described in the assessment reports as being "successful" or "likely successful" in monitoring reports (Figure 4a). These narrative descriptions rarely referred directly to monitoring data and when they did it was not unusual to find statements such as "the stream channel should begin to develop a suitable habitat for a basic benthic community" (e.g., Cow Creek Left Tributary, permit 2002-00265), "one can assume that the mitigation project will progress in such a manner that the stated goals will be achieved" (Unnamed Tributary to Clear Fork), and "with time, the habitat and stream should only continue to improve" (Evans Ferrell Branch, Permit 2002-

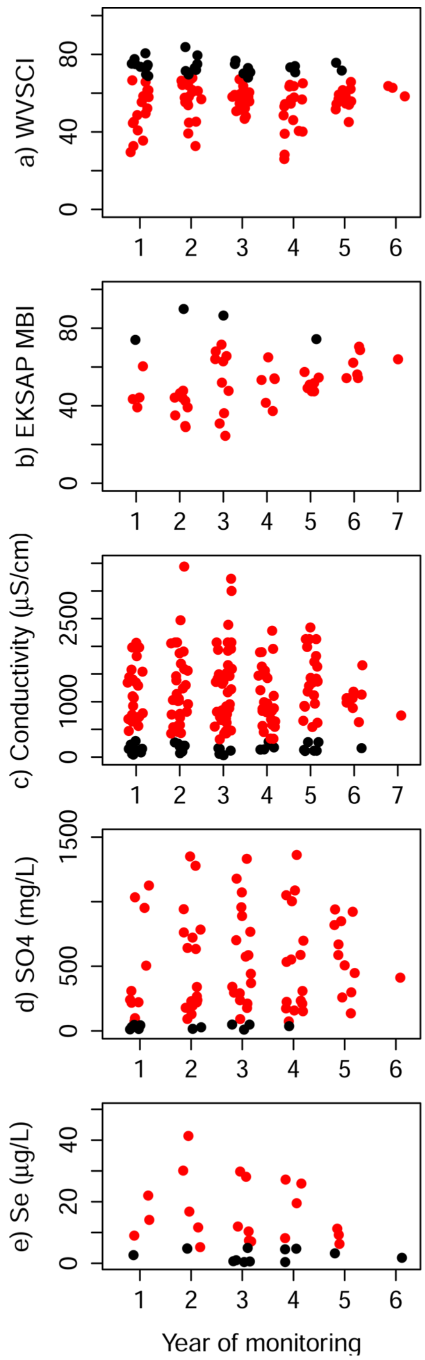

Figure 5. Biological and water quality reported for mitigation projects across years. (a) West Virginia Biological Index score (WVSCI) for projects reporting on biological condition. All projects with a WVSCI value of <68 are "impaired" (red data points) and would qualify for the WV 303d list;[57] (b) Kentucky Macroinvertebrate Biotic Index (MBI) score by year for projects reporting on biological condition. All projects with a MBI < 72 are "impaired" for these streams which are mountainous headwaters;[53] (c) conductivity, red points are measurements above thresholds conducive to aquatic life (300 μS/cm);[25] (d) sulfate, red points are measurements above thresholds conducive to aquatic life (50 mg/L);[26] (e) selenium, red points are measurements above EPA freshwater chronic criterion concentration (5 μg/L).[27]

00264). Because permittees were not required to meet quantitative water quality or biological standards even for mitigation projects reporting biological and conductivity scores indicative of serious impairment (e.g., first Unnamed Left Tributary of Sugartree Branch, Permit 2003-01379, WVSCI score 45.08, conductivity >1000 μS/cm in year 5) they are not being required to take any remedial actions. This was even true when scores were found to decline from year 1–5 (Bull Creek, permit 2004-00658 decreased from 73.58 WVSCI in year 1–58.35 WVSCI in year 6) and was true even for projects associated with permits that allowed the total loss of healthy, forested streams.

Overall the reports provide no evidence that stream mitigations being implemented for coal mining in the southern Appalachian states of Kentucky, Tennessee, Virginia, and West Virginia are meeting the objectives of the CWA to replace lost or degraded natural resource values and functions. Mitigation activities at best account for a replacement of resource area (stream length) which is assessed by structural attributes rather than an evaluation of resource functions. This is largely a function of the method of assigning mitigation requirements and of the performance standards used to evaluate the success of projects. The current compensatory mitigation regulations[13] require that "performance standards must be based on attributes that are objective and verifiable. Ecological performance standards must be based on the best available science that can be measured or assessed in a practicable manner"[13] (Federal Register page 19696, §230.95). Yet the assessment criteria and requirements for compliance in the projects reviewed do not meet basic scientific standards: they do not take measurements relevant to the factors of interest, they have conclusions inconsistent with the data, and are overall inadequate to assess the outcomes required by the CWA. Although ecological function and the status of affected streams are sometimes considered in assigning mitigation, requirements to collect that information were rare. By combining stream length and a scaling factor for quality into one metric of impact, the determination for what is adequate compensation assumes a fungibility between ecological functions and between quantity and quality—essentially, that a short length of higher quality stream is "worth" the same amount as a longer stream ranked as a lower quality.

IMPLICATIONS FOR MOVING FORWARD

The analysis for this study addresses important knowledge gaps associated with the four questions initially posed. Mitigation actions being undertaken are primarily geomorphic projects to enhance perennial streams yet the majority of streams impacted are intermittent and fewer linear feet of stream have been restored than impacted. Compliance is primarily based on visual habitat assessments performed by the mining company or their consultants which typically report marginal or suboptimal habitat status postrestoration. Projects were not required to meet specified biological or water quality standards yet for the projects that reported such data, most were impaired.

There is no evidence that mitigation is meeting the objectives of the CWA and looking forward there is no reason to believe this will change unless new mitigation requirements and scientifically rigorous assessments are put in place. The 2008 Mitigation Rule strengthened somewhat the performance standards for mitigation projects and only applies to permit applications submitted after June 9, 2008. Since the projects reviewed with sufficient monitoring data to evaluate outcomes were implemented prior to that date, a sample (N = 15) of recently approved mitigation plans for projects in WV was obtained. These newer projects now include performance criteria that require unimpaired WVSCI scores and compliance with state water quality standards. Unfortunately the restoration methods proposed in these newer comprehensive mitigation plans to meet those standards have not changed from the methods in the plans that were reviewed, for example, restoration projects still rely on NCD and as discussed earlier this geomorphic form-based method does not result in restoration of native biodiversity in biologically degraded streams and has not been shown to improve impaired water or biological integrity.[55] This means that not only have past mitigation actions failed in replacing stream structure and function but that future ones will likely perform the same way.

ASSOCIATED CONTENT

Supporting Information

Sections S1, S2. Figures S1, S2; Table S1, S2, S3, S4. This material is available free of charge via the Internet at http://pubs.acs.org

AUTHOR INFORMATION

Corresponding Author

*Phone: 410 919-4810; e-mail: mpalmer@umd.edu.

Notes

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