Subject Matter Expert Report: FOOD AVAILABILITY. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population

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EXECUTIVE SUMMARY

Recent monitoring and data analyses for the Harmer Creek and Grave Creek Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) populations indicate there was reduced recruitment for the 2017 to 2019 spawning year cohorts in the Harmer Creek population.[1] Additionally, the magnitude of reduced recruitment for the 2018 spawning year cohort in the Harmer Creek population was large enough to constitute recruitment failure. In contrast, recruitment in the Grave Creek population appears to have been at replacement levels in 2017 and 2019 and recruitment was above replacement for the 2020 spawn year in both the Harmer Creek and Grave Creek populations. When the low abundance of potential recruits was first reported, Teck Coal Limited (Teck Coal) promptly assembled a team of Subject Matter Experts (SMEs) to initiate an "Evaluation of Cause" (EoC). This document, which evaluates if a reduction in food availability contributed to reduced recruitment for the 2017 to 2019 spawning year cohorts in the Harmer Creek population, is one of a series of SME reports undertaken as part of the EoC.

Westslope Cutthroat Trout are opportunistic sight feeders that consume seasonally-abundant invertebrate prey, specifically aquatic invertebrates detected in the drift or on the substrates, with summer supplements of terrestrial invertebrates. Although the mouth or gape size of smaller juvenile Westslope Cutthroat Trout may limit the size of prey they are able to consume, there is considerable overlap in the aquatic invertebrate taxa consumed by free-feeding individuals. Aquatic invertebrates of the orders Ephemeroptera, (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which are collectively referred to as EPT, as well as Diptera (true flies), are important dietary items.

This report evaluated three lines of evidence related to food availability and each line of evidence is related to one of the following questions:

1. Did food limitations and subsequent starvation[2] cause or contribute to reduced recruitment for the Harmer Creek Westslope Cutthroat Trout population?

2. Did the quantity or quality of aquatic invertebrate prey decrease sufficiently to cause or contribute to food limitations for Westslope Cutthroat Trout and ultimately a reduction in recruitment?

[1] Reduced recruitment was also identified for the 2018 spawning year cohort in the Grave Creek population.

[2] In the context of this SME report, "starvation" is defined as a prolonged period of reduced caloric energy intake during which the energy obtained from food is less than the amount of energy required to carry out basic biological processes and, in extreme cases, maintain life.

3. Did the quantity or quality of terrestrial invertebrate prey in drift decrease sufficiently to cause or contribute to food limitations for Westslope Cutthroat Trout and ultimately a reduction in recruitment?

The first lines of evidence considered were growth (i.e., length) of free-feeding age-0 fish (i.e., fry) and fish condition (i.e., the relationship between fish weight and length) as indicators of starvation that could have resulted from food limitations (Question 1). However, because growth and condition can be influenced by factors other than food availability (e.g., temperature, redirection of energy to compensate for stressors in the environment), reduced growth or condition were not considered stand-alone evidence for food limitations. Analyses completed by other SMEs indicated that fry from the Harmer Creek population were likely smaller (based on length) than fry from the Grave Creek and Upper Fording River populations and could have failed to achieve a minimum size threshold for overwintering survival. Weight-at-length for juvenile fish (i.e., age-1 and age-2+ fish up to 170 millimetres [mm] fork length) indicated there were no significant differences between the Harmer Creek and Grave Creek populations in 2008, 2013, 2017, 2018, and 2020.[3] When the same weight-at-length data were evaluated over time, it appeared that juvenile Westslope Cutthroat Trout were marginally (i.e., less than or equal to [≤] 10 percent [%]) smaller in 2018 relative to 2017 and 2020, but not 2013. Fulton's condition factors (K) for juvenile fish (i.e., age-1 and age-2+ fish up to 170 mm fork length) from the two population areas were similar in each monitoring year, including years relevant to the reduction in recruitment; K was also consistent among years for juvenile fish from the Harmer Creek population area. For fish that were assumed to be adults based on fork lengths greater than 170 mm, mean weight-at-length was slightly higher in the Harmer Creek versus Grave Creek population. When evaluated over time, weight-at-length and condition factors for adult Westslope Cutthroat Trout from the Harmer Creek population were consistent among years, albeit slightly lower (4.3%) in 2018 relative to 2017. Overall, it appears some factor(s) may limit the sizes achieved by early life stages of fish in the Harmer Creek population.

The second line of evidence evaluated was the quantity and quality of the aquatic invertebrate food supply (Question 2). Benthic invertebrate abundance and community characteristics in 2016 to 2020 were compared to data collected in previous years to identify if food was limiting during the period of reduced recruitment. There was broad overlap in total abundances and abundances of major taxonomic groups (i.e., EPT taxa and dipterans) between the Harmer Creek and Grave Creek population areas. In both population areas, total benthic invertebrate abundances and EPT

[3] Too few juvenile fish were captured from the Harmer Creek population area in 2019 (n = 3) (Thorley et al. 2022) to support statistical comparisons between populations or relative to earlier years. Condition factors were calculated for the small numbers of juvenile fish captured in 2019, and these were compared qualitatively with condition factors for juvenile Westslope Cutthroat Trout from other Upper Kootenay River populations.

abundances were within or above the regional reference area normal ranges for data years after 2012, including the period of reduced recruitment. When considered separately, abundances of Ephemeroptera, Plecoptera, and Trichoptera were also generally within or above their respective regional reference area normal ranges, as were dipteran abundances. Limited data (i.e., two samples) indicated relatively low total benthic invertebrate abundance in Dry Creek (Harmer Creek population area) in 2020; however, results were within the range observed at reference areas unimpacted by mining. Additionally, calcification of the substrates in Dry Creek and any related effects to the local benthic invertebrate communities would have been realized in the period of mine development leading up to the period of reduced recruitment (i.e., were not unique to 2016 to 2020). Total benthic invertebrate abundances did not decrease significantly over time in the Harmer Creek population area during the period of reduced Westslope Cutthroat Trout recruitment. Additionally, the abundances of EPT and individual taxonomic groups (including Ephemeroptera, Plecoptera, Trichoptera, and Diptera) in the Harmer Creek population area did not decrease significantly over time during the period of reduced recruitment.

Relative taxon proportions (%) in invertebrate samples were evaluated as an indicator of potential differences in food quality among areas and over time. Proportions of EPT taxa were within or above the regional reference area normal range for most biological monitoring areas and years, except for some localized benthic invertebrate community effects observed in Dry Creek in 2020. The Dry Creek community had relatively fewer Ephemeroptera and more Diptera compared to reference area normal ranges. Proportions of Diptera were also within or above the regional reference area normal range at mine-exposed monitoring areas in the Harmer Creek and Grave Creek population areas. There were no major shifts in community composition over time (2012 to 2020) within the Harmer Creek population area.

To evaluate potential reductions in terrestrial invertebrate supply to aquatic drift (Question 3), riparian habitat and mine disturbance areas in 2020 were compared to conditions prior to September 2016. The total areas of riparian habitat and land disturbed by mining and other causes (e.g., fire, forestry) within both the Harmer Creek and Grave Creek population areas were unchanged during this time.

Taken together, these lines of evidence indicate that food limitations following changes to the quantity and quality of aquatic and terrestrial invertebrate prey was unlikely to have caused or been a major contributor to the reduced recruitment for the 2017 to 2019 spawning year cohorts in the Harmer Creek Westslope Cutthroat Trout population.

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ACRONYMS AND ABBREVIATIONS

ADIT – Aquatic Data Integration Tool

AMP – Adaptive Management Plan

ANCOVA – Analysis of Covariance

ANOVA – Analysis of Variance

ATU – Accumulated Thermal Units

BC – British Columbia

BEC – Biogeoclimatic Ecosystem Classifications

CABIN – Canadian Aquatic Biomonitoring Network

CWB – Corporate Watershed Base

Ecofish – Ecofish Research Ltd.

EEM – Environmental Effects Monitoring

EoC – Evaluation of Cause

EPT – Ephemeroptera, Plecoptera, and Trichoptera

ESSF – Englemann Spruce- Subalpine Fir

EVO – Elkview Operation

EVWQP – Elk Valley Water Quality Plan

FRO – Fording River Operation

GHO – Greenhills Operation

GIS – Geographic Information Systems

Golder – Golder Associates

HSD – Honestly Significant Difference

IMAun – Undifferentiated Interior Mountain

K – Fulton's Condition Factor

LAEMP – Local Aquatic Effects Monitoring Program

LPL – Lowest Practical Level

MCT – Measure of Central Tendency

Minnow – Minnow Environmental Inc.

MOD – Magnitude of Difference

RAEMP – Regional Aquatic Effects Monitoring Program

R^2 – Coefficient of Determination

R.P.Bio. – Registered Professional Biologist

SME – Subject Matter Expert

SD – Standard Deviation

Teck Coal – Teck Coal Limited

TEM – Terrestrial Ecosystem Mapping

TRIM – Terrain Resource Information Management

READER'S NOTE

Background

The Elk Valley (Qukin ʔamaʔkis) is located in the southeast corner of British Columbia (BC), Canada. "Ktunaxa people have occupied Qukin ʔamaʔkis for over 10,000 years. The value and significance of ʔa·kxamis ʼqapi qapsin (All Living Things) to the Ktunaxa Nation and in Qukin ʔamaʔkis must not be understated" (text provided by the Ktunaxa Nation Council [KNC]).

The Elk Valley contains the main stem of the Elk River, and one of the tributaries to the Elk River is Grave Creek. Grave Creek has tributaries of its own, including Harmer Creek. Harmer and Grave Creeks are upstream of a waterfall on Grave Creek, and they are home to isolated, genetically pure Westslope Cutthroat Trout (WCT; *Oncorhynchus clarkii lewisi*). This fish species is iconic, highly valued in the area and of special concern under federal and provincial legislation and policy.

In the Grave Creek watershed[4], the disturbance from logging, roads and other development is limited. The mine property belonging to Teck Coal Limited's Elkview Operations includes an area in the southwest of the Harmer Creek subwatershed. These operations influence Harmer Creek through its tributary Dry Creek, and they influence Grave Creek below its confluence with Harmer Creek (Harmer Creek Evaluation of Cause, 2022)[5]. Westslope Cutthroat Trout populations in both Harmer and Grave Creeks are part of Teck Coal's monitoring program.

The Evaluation of Cause Process

The Process Was Initiated

Teck Coal undertakes aquatic monitoring programs in the Elk Valley, including fish population monitoring. Using data collected as part of Teck Coal's monitoring program, Cope & Cope (2020) reported low abundance of juvenile WCT in 2019, which appeared to be due to recruitment failure in Harmer Creek. Teck Coal initiated an Evaluation of Cause — a process to evaluate and report on what may have contributed to the apparent

[4] Including Grave and Harmer Creeks and their tributaries.

[5] Harmer Creek Evaluation of Cause Team. (2023). *Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population*. Report prepared for Teck Coal Limited.

recruitment failure. Data were analyzed from annual monitoring programs in the Harmer and Grave Creek population areas[6] from 2017 to 2021 (Thorley et al. 2022; Chapter 4, Evaluation of Cause), and several patterns related to recruitment[7] were identified:

- *Reduced Recruitment*[8] occurred during the 2017, 2018 and 2019 spawn years[9] in the Harmer Creek population and in the 2018 spawn year in the Grave Creek population.
- The magnitude of Reduced Recruitment in the Harmer Creek population in the 2018 spawn year was significant enough to constitute *Recruitment Failure*[10].
- Recruitment was *Above Replacement*[11] for the 2020 spawn year in both the Harmer and Grave Creek populations.

The recruitment patterns from 2017, 2018 and 2019 in Harmer Creek are collectively referred to as Reduced Recruitment in this report. To the extent that there are specific nuances within 2017-2019 recruitment patterns that correlate with individual years, such as the 2018 Recruitment Failure, these are referenced as appropriate.

How the Evaluation of Cause Was Approached

When the Evaluation of Cause was initiated, an *Evaluation of Cause Team* (the Team) was established. It was composed of *Subject Matter Experts* (SMEs) who evaluated stressors with the potential to impact the WCT population. Further details about the Team are provided in the Evaluation of Cause report (Harmer Creek Evaluation of Cause Team, 2023).

During the Evaluation of Cause process, the Team had regularly scheduled meetings with representatives of the KNC and various agencies (the participants). These meetings included discussions about the overarching question that would be evaluated and about technical issues, such as identifying potential stressors, natural and anthropogenic, which had the potential to

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[6] Grave Creek population area" includes Grave Creek upstream of the waterfall at river kilometer (rkm) 2.1 and Harmer Creek below Harmer Sedimentation Pond. "Harmer Creek population area" includes Harmer Creek and its tributaries (including Dry Creek) from Harmer Sedimentation Pond and upstream.

[7] Recruitment refers to the addition of new individuals to a population through reproduction.

[8] For the purposes of the Evaluation of Cause, Reduced Recruitment is defined as a probability of > 50% that annual recruitment is <100% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

[9] The spawn year is the year a fish egg was deposited, and fry emerged.

[10] For the purposes of the Evaluation of Cause, Recruitment Failure is defined as a probability of > 50% that annual recruitment is <10% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

[11] For the purposes of the Evaluation of Cause, Above Replacement is defined as a probability of > 50% that annual recruitment is >100% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

impact recruitment in the Harmer Creek WCT population. This was an iterative process driven largely by the Team's evolving understanding of key parameters of the WCT population, such as abundance, density, size, condition and patterns of recruitment over time. Once the approach was finalized and the data were compiled, SMEs presented methods and draft results for informal input from participants. Subject Matter Experts then revised their work to address feedback and, subsequently, participants reviewed and commented on the reports. Finally, results of the analysis of the population monitoring data and potential stressor assessments were integrated to determine the relative contribution of each potential stressor to the Reduced Recruitment in the Harmer Creek population.

The Overarching Question the Team Investigated

The Team investigated the overarching question identified for the Evaluation of Cause, which was:

> **What potential stressors can explain changes in the Harmer Creek Westslope Cutthroat Trout population over time, specifically with respect to Reduced Recruitment?**

The Team developed a systematic and objective approach to investigate the potential stressors that could have contributed to the Reduced Recruitment in the Harmer Creek population. This approach is illustrated in the figure that follows the list of deliverables, below. The approach included evaluating patterns and trends, over time, in data from fish monitoring and potential stressors within the Harmer Creek population area and comparing them with patterns and trends in the nearby Grave Creek population area, which was used as a reference. The SMEs used currently available data to investigate causal effect pathways for the stressors and to determine if the stressors were present at a magnitude and for a duration sufficient to have adversely impacted the WCT. The results of this investigation are provided in two types of deliverables:

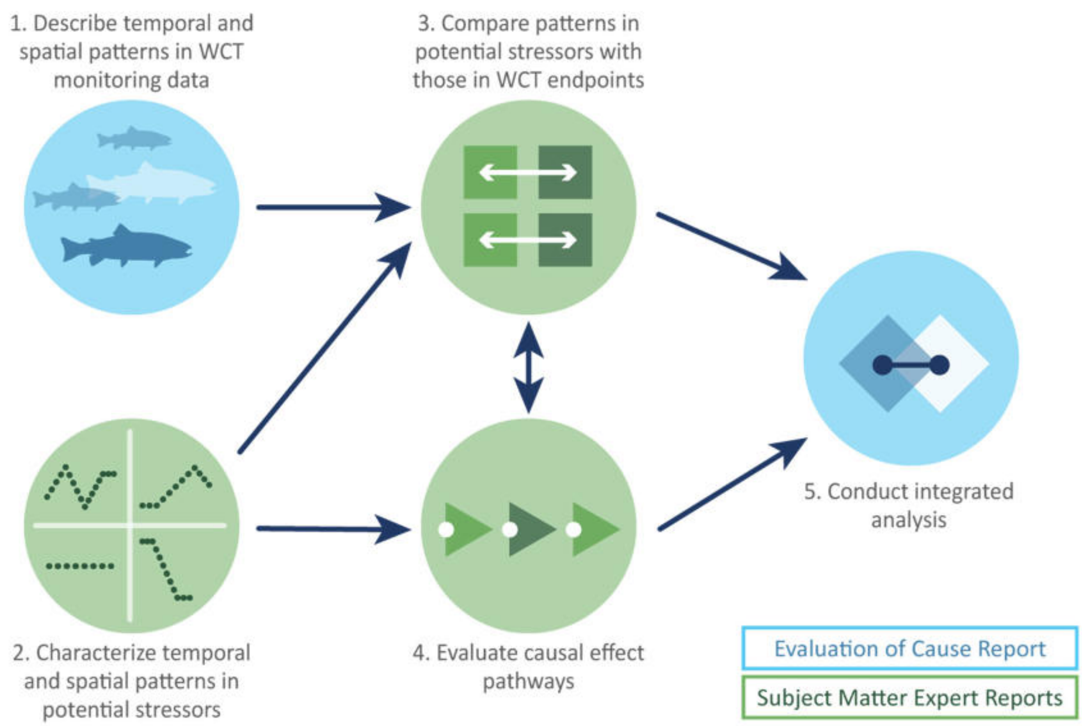
1. Individual Subject Matter Expert reports (such as the one that follows this Note). Potential stressors were evaluated by SMEs and their co-authors using the available data. These evaluations were documented in a series of reports that describe spatial and temporal patterns associated with the potential stressors, and they focus on the period of Reduced Recruitment, including the Recruitment Failure of the 2018 spawn year where appropriate. The reports describe if and to what extent potential stressors may explain the Reduced Recruitment.

The full list of Subject Matter Expert reports follows at the end of this Reader's Note.

2. The Evaluation of Cause report. The SME reports provided the foundation for the Evaluation of Cause report, which was prepared by a subset of the Team and included input from SMEs.

   The Evaluation of Cause report:

   a. Provides readers with context for the SME reports and describes Harmer and Grave Creeks, the Grave Creek watershed, the history of development in the area and the natural history of WCT in these creeks
   b. Presents fish monitoring data, which characterize the Harmer Creek and Grave Creek populations over time
   c. Uses an integrated approach to assess the role of each potential stressor in contributing to Reduced Recruitment in the Harmer Creek population area.



Conceptual approach to the Evaluation of Cause for the Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout population.

Participation, Engagement & Transparency

To support transparency, the Team engaged frequently with participants throughout the Evaluation of Cause process. Participants in the Evaluation of Cause process, through various committees, included:

- Ktunaxa Nation Council
- BC Ministry of Forests,
- BC Ministry of Land, Water and Resource Stewardship
- BC Ministry Environment & Climate Change Strategy
- Ministry of Energy, Mines and Low Carbon Innovation
- Environmental Assessment Office

Citations for Evaluation of Cause Team Reports

Focus	Citation
Harmer Creek Evaluation of Cause report	Harmer Creek Evaluation of Cause Team. (2023). *Evaluation of Cause - Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited.
Calcite	Hocking, M. A., Cloutier, R. N., Braga, J., & Hatfield, T. (2022). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Dissolved oxygen	Abell, J., Yu, X., Braga, J., & Hatfield, T. (2022). *Subject Matter Expert Report: Dissolved Oxygen. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.

Focus	Citation
Energetic Status	Thorley, J.L. & Branton, M.A. (2023) *Subject Matter Expert Report: Energetic Status at the Onset of Winter Based on Fork Length and Wet Weight. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population*. Report prepared for Teck Coal Limited. Prepared by Poisson Consulting Ltd and Branton Environmental Consulting.
Food availability	Wiebe, A., Orr, P., & Ings, J. (2022). *Subject Matter Expert Report: Food Availability. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.
Groundwater	Canham, E., & Humphries, S. (2022). *Evaluation of Groundwater as a Potential Stressor to Westslope Cutthroat Trout in the Harmer and Grave Creek Watersheds.* Memo prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.
Habitat availability (instream flow)	Wright, N., Little, P., & Hatfield, T. (2022). *Subject Matter Expert Report: Streamflow and Inferred Habitat Availability. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Sediment quality	Wiebe, A., Orr, P., & Ings, J. (2022). Subject Matter Expert Report: Sediment Quality. *Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population*. Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.

Focus	Citation
Selenium	de Bruyn, A., Bollinger, T., & Luoma, S. (2022). *Subject Matter Expert Report: Selenium. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by ADEPT Environmental Sciences Ltd, TKB Ecosystem Health Services, and SNL PhD, LLC.
Small population size	Thorley, J. L., Hussein, N., Amish, S. J. (2022). *Subject Matter Expert Report: Small Population Size. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Poisson Consulting and Conservation Genomics Consulting, LLC.
Telemetry analysis	Akaoka, K., & Hatfield, T. (2022). *Harmer and Grave Creeks Telemetry Movement Analysis.* Memo prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Total suspended solids	Durston, D., & Hatfield, T. (2022). *Subject Matter Expert Report: Total Suspended Solids. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Water quality	Warner, K., & Lancaster, S. (2022). *Subject Matter Expert Report: Surface Water Quality. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by WSP-Golder.
Water temperature and ice	Hocking, M., Whelan, C. & Hatfield, T. (2022). *Subject Matter Expert Report: Water Temperature and Ice. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.

1 INTRODUCTION

1.1 Background

1.1.1 Overall Background

Teck Coal Limited (Teck Coal) undertakes aquatic monitoring programs in the Elk Valley, including fish population monitoring. The Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in Harmer Creek and Grave Creek were monitored in 1996, 2008, and 2013 and then annually since 2017. Based on data collected from 2017 to 2019, low abundances of juvenile Westslope Cutthroat Trout were reported (Cope and Cope 2020) and were considered indicative of recruitment failure in Harmer Creek. Teck Coal initiated an "Evaluation of Cause" (EoC) to evaluate and report on what may have contributed to the apparent recruitment failure. Data from annual monitoring programs completed in the Harmer and Grave Creek population areas[12] from 2017 to 2021 were analyzed (Chapter 4 of the EoC report [Harmer Creek Evaluation of Cause Team 2023]; Thorley et al. 2022) and several patterns related to recruitment[13] were identified:

- *Reduced recruitment*[14] occurred during the 2017, 2018, and 2019 spawn years[15] in the Harmer Creek population and in the 2018 spawn year in the Grave Creek population.
- The magnitude of reduced recruitment in the Harmer Creek population in the 2018 spawn year was large enough to constitute *recruitment failure*[16].
- Recruitment was *above replacement*[17] for the 2020 spawn year in both the Harmer and Grave Creek populations.

[12] The "Grave Creek population area" includes Grave Creek upstream of the waterfall and Harmer Creek downstream from the Harmer Creek Sedimentation Pond. The "Harmer Creek population area" includes Harmer Creek and its tributaries (including Dry Creek) upstream from the dam at the downstream end of the Harmer Creek Sedimentation Pond.

[13] Recruitment refers to the addition of new individuals to a population through reproduction.

[14] For the purposes of the EoC, reduced recruitment is defined as a probability of greater than (>) 50 percent (%) that annual recruitment was less than (<) 100% of that required for population replacement (see Chapter 4 of the EoC report [Harmer Creek Evaluation of Cause Team 2023]).

[15] The spawn year is the year a fish egg was deposited and fry emerged.

[16] For the purposes of the EoC, recruitment failure is defined as a probability of >50% that annual recruitment was <10% of that required for population replacement (see Chapter 4 of the EoC report [Harmer Creek Evaluation of Cause Team, 2023]).

[17] For the purposes of the EoC, recruitment above replacement is defined as a probability of >50% that annual recruitment is >100% of that required for population replacement (see Chapter 4 of the EoC report [Harmer Creek Evaluation of Cause Team 2023]).

The recruitment patterns in Harmer Creek from 2017 to 2019 are collectively referred to as *reduced recruitment* in this report. To the extent that there are specific nuances within the 2017 to 2019 recruitment patterns that correlate with individual years, such as the 2018 *recruitment failure*, these are referenced as appropriate.

The EoC project team investigated one overarching question: **What potential stressors can explain changes in the Harmer Creek Westslope Cutthroat Trout population over time, specifically with respect to patterns of reduced recruitment?** Investigating the overarching question included evaluating trends in both Westslope Cutthroat Trout population parameters (e.g., abundance, condition, recruitment) and the potential stressors[18] that could impact these parameters. Trends in Westslope Cutthroat Trout population parameters were evaluated based on monitoring data collected from 2017 to 2021 (Chapter 4 of the EoC report [Harmer Creek Evaluation of Cause Team 2023]; Thorley et al. 2022). The Grave Creek population area was use as a reference area for this evaluation.

The approach taken in the EoC to analyze potential stressors was to (1) characterize trends in each stressor for the Harmer Creek and Grave Creek populations; (2) compare the trends between the two population areas; (3) identify any changes in Harmer Creek during the period of reduced recruitment, including the recruitment failure of the 2018 spawn year, as appropriate, and (4) evaluate how each stressor trended relative to fish population parameters. The mechanisms by which the potential stressors could impact Westslope Cutthroat Trout were identified and it was determined if stressors were present at sufficient magnitude and duration to adversely affect Westslope Cutthroat Trout during the period of reduced recruitment. Together, these analyses were used in the EoC report to support conclusions regarding the relative contribution of each potential stressor to the reduced recruitment observed in the Harmer Creek population area.

This document is one of a series of Subject Matter Expert (SME) reports that support the overall Harmer Creek Westslope Cutthroat Trout EoC (Harmer Creek Evaluation of Cause Team 2023). For additional information, see the preceding Reader's Note.

[18] The EoC process was initiated early in 2021 with currently available data. Although the process continued through mid-2022, data collected in 2021 were not included in the EoC because most stressor reports were already complete. Exceptions were made for the 2021 fish monitoring data and (1) selenium data because the selenium report was not complete and substantive new datasets were available, and (2) water temperature data for 2021 in the temperature report because a new sampling location was added in upper Grave Creek that contributed to our understanding of the Grave Creek population area.

1.1.2 Report-specific Background

This report describes the investigation of a potential reduction in food availability as a causal or contributing factor in the reduced recruitment observed for the Harmer Creek Westslope Cutthroat Trout population.

Stream resident populations of Westslope Cutthroat Trout, like the Harmer Creek and Grave Creek populations, often inhabit small, isolated headwater streams and seldom exceed 250 to 300 millimetres (mm) fork length (Cope and Cope 2020; Thorley et al. 2021). Fluvial and adfluvial migratory Westslope Cutthroat Trout identified in larger Kootenay rivers (e.g., Upper Fording River, St. Mary River, and Elk River; Cope et al. 2016; Morris and Prince 2004; Prince and Morris 2003) can attain sizes of 300 mm to greater than (>) 500 mm (Cope et al. 2014; McIntyre and Rieman 1995; Shepard et al. 1984).

Spawning of Westslope Cutthroat Trout is typically observed on the declining hydrograph of the spring freshet (Cope et al. 2014). After spawning, embryos generally incubate in the spawning gravels for six to seven weeks, depending on water temperature. Once hatched, alevins (age-0) remain in the substrate until their yolk sac has been absorbed and emerge from the streambed as fry (age-0) at approximately 20 mm fork length (Scott and Crossman 1998). Emergence can occur as early as July in some systems (COSEWIC 2016); however, because Harmer and Grave creeks are relatively cold, the incubation period, which is determined by accumulated thermal units (ATU) may extend into October (Harmer Creek Evaluation of Cause Team 2023). Recent length-frequency analyses completed by Thorley et al. (2022) indicated that age-1 fish from the Harmer Creek and Grave Creek populations were between 45 to 94 mm and 55 to 99 mm fork length, respectively.

Age-at-maturity for Westslope Cutthroat Trout can vary among populations and between sexes. Males in isolated headwater populations can mature as early as age-2 (Downs et al. 1997) and all males are typically mature by age-4, whereas age at first maturation for females is typically age-3 to age-5. For most assessments, Westslope Cutthroat Trout age-3 and older are classified as adults because a substantial proportion of individuals in this age group can be expected to be sexually mature (Downs et al. 1997; Liknes and Graham 1988; Shepard et al. 1997). For Harmer and Grave creeks, Cope and Cope (2020) classified fish with fork lengths greater than or equal to (≥) 150 mm as adults. However, based on the Harmer Creek Evaluation of Cause Team's (2023) recent re-evaluation of the available information on size-at-maturity, fish from Harmer and Grave creeks with fork lengths greater than 170 mm were reclassified as adults.

Throughout this SME report, references to embryos, alevins, fry, juveniles, and adults are based on the size and/or age groupings as follows:

- **Embryos:** from spawning until hatch, which typically occurs approximately six to seven weeks post-spawn;
- **Alevins:** from hatch until yolk sac absorption, which occurs at approximately 20 mm fork length;
- **Fry:** from swim-up at about 20 mm fork length until the January following their spawn year, when they are considered age-1;
- **Juveniles:** individuals that are age-1 or age-2+ and have fork lengths less than 170 mm; and
- **Adults:** individuals with fork lengths ≥170 mm.

Westslope Cutthroat Trout, like other salmonids, are opportunistic sight feeders that mainly consume whatever invertebrate prey items are seasonally abundant in drift (COSEWIC 2006, 2016; Elliot 1973; Fraser and Metcalfe 1997; Nakano et al. 1999). Inland cutthroat trout have evolved to be invertebrate specialists, unlike the coastal variety of cutthroat trout, which consume fish in addition to invertebrates (Nowak et al. 2004; Shepard et al. 1984). Fry and juvenile Westslope Cutthroat Trout tend to occupy back-water habitats, eddies, and stream margins where they consume small prey, such as chironomid larvae (Costello 2006; Government of Canada 2019; Kelly et al. 1988). Adult and larger juvenile Westslope Cutthroat Trout typically occupy deeper pools and runs with abundant cover and large woody debris where they feed on a diverse diet of aquatic and terrestrial invertebrates (COSEWIC 2006, 2016; Government of Canada 2019). There are considerable overlaps of the taxa and sizes of invertebrate prey consumed by different life stages of cutthroat trout (e.g., Diptera are commonly consumed by both juvenile and adult Westslope Cutthroat Trout; Bozek et al. 1994; Government of Canada 2019).

Similar to other inland populations of this species (COSEWIC 2006, 2016; Costello 2006; Government of Canada 2019), aquatic invertebrate prey of Westslope Cutthroat Trout in the Elk River watershed, British Columbia (BC) are mainly larval or adult forms of one or more of the following aquatic invertebrate groups: true flies (Diptera), mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (EVS-Golder 2005; Lister and KWL 1980; Minnow 2004; unpublished data from Minnow et al. 2011). Terrestrial invertebrates in drift are also consumed (Lister and KWL 1980; McDonald and Strosher 1998). Consumption of terrestrial invertebrates by trout is typically highest in summer and fall when terrestrial invertebrates are of greater size (and therefore easier to detect) and/or more seasonally available than aquatic invertebrates in drift (Li et al. 2016; Romaniszyn et al. 2007; Studinski et al. 2017; Sweka and Hartman 2008; Wipfli 1997). The relative proportions of aquatic versus terrestrial prey in trout diets can vary widely among streams and years (Baxter et al. 2005; Sepulveda 2017; Wipfli 1997). Overall or total abundance of drifting invertebrates in temperate streams is typically lowest in winter (Romaniszyn et al. 2007; Syrjänen et al. 2011). Food consumption and assimilation rates in fish tend to be highest in spring/summer and decline in fall/winter when water temperatures decrease (Li et al. 2016; Thayer 2016).

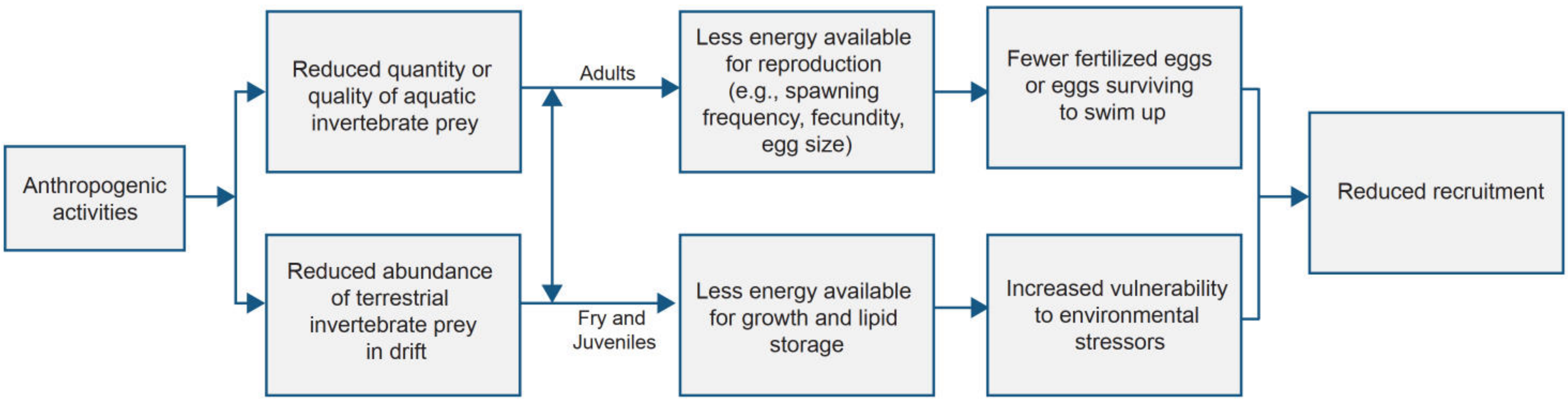
Based on the overall understanding of Westslope Cutthroat Trout and their dietary habits, the investigation described in this SME report focused on two potential pathways of effect related to the reduced recruitment in the Harmer Creek Westslope Cutthroat Trout population (Figure 1.1):

1. A decline in abundance and/or quality of aquatic invertebrate prey that could have resulted in food limitations and, ultimately, reduced recruitment; and
2. A decline in abundance and/or quality of terrestrial invertebrate prey that could have resulted in food limitations and, ultimately, reduced recruitment.

Growth (length) of fry prior to their first winter and fish condition (weight-at-length) were evaluated as indicators of starvation (i.e., a prolonged period of reduced caloric energy intake during which the energy obtained from food is less than the amount of energy required to carry out basic biological processes and, in extreme cases, maintain life) that could have resulted from food limitations. However, it is recognized that factors other than food availability can induce starvation or affect fish growth/size and energy stores/condition (i.e., reduced growth and condition are not stand-alone evidence for food limitations). For example, Coleman and Fausch (2007a) determined that colder temperatures (i.e., an average of 7 degrees Celsius [°C]) in the four to six weeks following swim-up can result in lower energy stores and poor overwinter survival. Additionally, the metabolic costs of responding to environmental stressors are known to reduce growth rates in fish, including early life stages of salmonids (Marr et al. 1996). The roles of temperature and water and sediment quality stressors in the reduced recruitment for the Harmer Creek Westslope Cutthroat Trout population were assessed in detail in other SME reports (de Bruyn et al. 2022; Hocking et al. 2022; Warner and de Bruyn 2022; Wiebe et al. 2022).

1.1.3 Author Qualifications

This project was managed by Ms. Amy Wiebe, who has a Master of Science degree in toxicology from the University of Saskatchewan and is a Registered Professional Biologist (R.P.Bio.). She has worked on a wide variety of projects related to aquatic toxicology, fish habitat, and fish health for proponents throughout western and northern Canada. Ms. Wiebe has more than 10 years of aquatic environmental consulting experience and has been managing projects for Teck Coal since joining Minnow Environmental Inc. (Minnow) in 2018. She is currently



Causal Effects Pathway Diagram

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Figure 1.1

responsible for the design and implementation of monitoring programs to support Teck Coal's Greenhills Operation (GHO) and is a senior project advisor for the Study of the Reproductive Effects of Selenium on Columbia Spotted Frog (*Rana luteiventris*). Ms. Wiebe also recently managed an in-depth, multi-year study of lentic (slow-flowing or stagnant) aquatic habitats in the Elk River watershed.

Ms. Patricia Orr, who has a Master of Science degree from the University of Waterloo, specializing in aquatic biology and toxicology, fulfilled the role of senior project advisor. She has been working in aquatic environmental consulting since 1986 and was a co-founder of Minnow in 2000. Ms. Orr has been a consultant to Teck Coal and previous owners of the Elk Valley coal mines since 2002, managing a variety of projects such as: an investigation of the bioaccumulation and potential effects of aqueous selenium in lotic (flowing) and lentic aquatic habitats of the Elk River watershed downstream from coal mining; the design and implementation of local and regional aquatic effects monitoring programs; design and completion of various supporting studies; and provision of technical support to Teck Coal's Elk Valley Water Quality Plan (EVWQP), Adaptive Management Plan (AMP), and Tributary Management Plan. In addition to projects in the Elk River watershed, Ms. Orr has worked extensively across Canada to design and undertake studies evaluating the effects of effluents from metal mines (operating and closed/abandoned sites) and pulp and paper mills on aquatic receiving environments. She was the project manager responsible for developing the first Technical Guidance Document for Environmental Effects Monitoring (EEM) studies completed under the federal *Fisheries Act* and has also participated in the development of generic (federal and provincial) water quality guidelines, and various site-specific guidelines.

Dr. Jennifer Ings fulfilled the role of senior reviewer. Dr. Ings has a Doctor of Philosophy degree from the University of Waterloo, specializing in aquatic ecotoxicology, and completed two postdoctoral fellowships with renowned researchers in the field. She has worked on a large variety of projects related to the impact of anthropogenic effluents on the aquatic environment since 2001, including but not limited to pulp and paper mill effluent, municipal wastewater effluent, and oilsands process-affected waters. Dr. Ings has been working at Minnow since 2015 and has been managing projects for Teck Coal since 2017. She is currently in the role of Client Manager for Teck Coal and is a senior project advisor for a number of programs including the Regional Aquatic Effects Monitoring Program (RAEMP), the Fording River Operation (FRO) Local Aquatic Effects Monitoring Program (LAEMP), and the Elkview Operation (EVO) LAEMP, among other projects.

1.2 Objective

The objective of this report was to investigate a potential decline in food availability to the Harmer Creek Westslope Cutthroat Trout population. The implicit, overarching concern associated with food availability is that food limitations may have led to reduced energy stores for adult spawners and/or fry (i.e., reduced length and/or condition) and, subsequently, impaired reproduction (Scott 1962) and/or higher size-selective overwintering mortality, respectively (Coleman and Faush 2007a,b). Therefore, the specific impact hypotheses that were investigated to determine if food availability may have caused or contributed to the reduced recruitment for the 2017 to 2019 spawning year cohorts (Cope and Cope 2020; Harmer Creek Evaluation of Cause Team 2023; Thorley et al. 2022) were:

1. Did food limitations and subsequent starvation reduce overwintering size for fry or reduce energy stores for free-feeding life stages (including adult spawners), thereby potentially causing or contributing to reduced recruitment of Westslope Cutthroat Trout?

2. Did the quantity or quality of aquatic invertebrate prey decrease sufficiently to cause or contribute to food limitations for Westslope Cutthroat Trout and ultimately to reduced recruitment?

3. Did the quantity or quality of terrestrial invertebrate prey in drift decrease sufficiently to cause or contribute to food limitations for Westslope Cutthroat Trout and ultimately to reduced recruitment?

1.3 Approach

The evaluation of potential changes in food availability to the Harmer Creek Westslope Cutthroat Trout population focused on three lines of evidence (Table 1.1). The first line of evidence involved an evaluation of fish size (length) and condition (i.e., the relationship between fish weight and length). Fish size and condition represent evidence of starvation, and potentially evidence of food limitations that could have caused or contributed to the reduced recruitment of the 2017 to 2019 spawning year cohorts in the Harmer Creek population. The second line of evidence involved an evaluation of potential changes in aquatic food supply. To evaluate a potential reduction in aquatic invertebrate supply to drift in the Harmer Creek population area, benthic invertebrate abundance and community characteristics were compared among years (from 2012 to 2020) and locations (i.e., in the Harmer Creek versus Grave Creek population areas; see Section 2.2.1 for additional background). The third line of evidence involved the evaluation of potential changes in terrestrial food supply. To evaluate a potential reduction in terrestrial invertebrate supply to aquatic drift, riparian habitat and mine disturbance areas in 2020 were compared to conditions in 2016 (see Section 2.3.1 for additional background).

Table 1.1: Lines of Evidence for Evaluating Potential Decreases in Food Availability as Causal or Contributing Factors for Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population

Lines of Evidence	Questions	Information Evaluated
1. Fish Size and Condition	Did food limitations reduce overwintering size of age-0 fish or reduce energy stores for free-feeding life stages, thereby potentially causing or contributing to reduced recruitment of WCT?	Potential decrease in WCT condition starting in 2017 relative to before: - Condition factor (k) - Weight-at-length Length of age-0 WCT (as an indicator of growth)
2. Aquatic Invertebrate Availability	Did the quantity or quality of aquatic invertebrate prey decrease sufficiently to cause or contribute to food limitations for WCT and ultimately to reduced recruitment?	Scientific literature regarding WCT food preferences and feeding behaviour Potential decreases in benthic invertebrate quantity (e.g., abundance) and changes in community composition (i.e., quality) starting in fall 2016 compared to before
3. Terrestrial Invertebrate Availability	Did the quantity or quality of terrestrial invertebrate prey in drift decrease sufficiently to cause or contribute to food limitations for WCT and ultimately to reduced recruitment?	Scientific literature regarding WCT food preferences and feeding behaviour Potential decreases in riparian habitat or vegetated land cover that may have reduced terrestrial invertebrate inputs to the Harmer Creek population area starting in fall 2016 compared to before

Notes: WCT = Westslope Cutthroat Trout.

Westslope Cutthroat Trout fry, juveniles, and adults occupying habitats throughout the Harmer Creek population area were considered directly relevant to this evaluation (Figure 1.1). Specifically, growth and condition of the 2017 to 2019 spawning year cohorts could have been affected while they were still considered fry (i.e., age-0; from emergence to January of the following year) or first-year juveniles (i.e., age-1; from the first January post-spawn until monitoring in September). Body condition data for adult spawners were considered indicative of the energy available for reproduction (Figure 1.1). However, data for all size classes of Westslope Cutthroat Trout with fork lengths ≥65 mm were included in the evaluation of fish condition because it was anticipated that reduced weight-at-length for any grouping of fish may be evidence for food limitations affecting adult spawners or the 2017 to 2019 spawning year cohorts (see Section 2.1). Data for the adjacent Grave Creek Westslope Cutthroat Trout population were used as a basis of comparison to identify conditions that were unique to the Harmer Creek population area during the period of reduced recruitment.

For a reduction in food availability to explain the reduced recruitment for the Harmer Creek Westslope Cutthroat Trout population, the data evaluation would be expected to show the following results:

- a reduction in body condition of adult spawners (beginning in late 2016[19], leading up to the 2017 to 2019 spawning years) within the Harmer Creek population, but not the Grave Creek population;
- a reduction in body length of fry in 2017 to 2019 among the Harmer Creek population and not the Grave Creek population, and relative to thresholds for size-selective overwintering mortality (e.g., Coleman and Fausch 2006);
- a reduction in body condition of juveniles[20] (in 2017 through 2020) among the Harmer Creek population and not the Grave Creek population;
- reduced total abundance or shifts in relative abundance of aquatic prey organisms (e.g., Ephemeroptera, Plecoptera, and Trichoptera [collectively referred to as EPT] and Diptera), which are the main food source for Westslope Cutthroat Trout, in the Harmer

[19] Although body condition of adult spawners starting in late 2016 would be considered relevant to the 2017 spawn year (i.e., the first year of the period of interest for reduced recruitment), no fish monitoring was completed in 2016 and no length or weight data are available.

[20] As indicated previously, the 2017, 2018, and 2019 spawning year cohorts were not monitored until September 2018, 2019, and 2020, respectively, when they would be considered juveniles based on the classifications presented in Section 1.1.2. Although the 2017 spawning year cohort was not monitored in September 2017, poorer condition for larger juvenile and adult fish in September 2017 might have signaled that food availability was poor for fry going into the winter of 2017.

Creek population area compared to the Grave Creek population area immediately preceding or during the period of reduced recruitment;

- greater loss of riparian habitat and undisturbed land within in the Harmer Creek population area than the Grave Creek population area that could have reduced the abundance or quality of terrestrial invertebrates in the drift; and
- effects to the aquatic or terrestrial food base in the Harmer Creek population area that were large in magnitude and widespread in area in order to explain such a large magnitude of effect on Westslope Cutthroat Trout recruitment. This is because fry, juvenile, and adult trout can shift between consuming both aquatic and terrestrial invertebrates in drift, or even to benthic invertebrates, depending on food availability (Dunham et al. 2000; Kraus et al. 2016; Nakano et al. 1999; Syrjänen et al. 2011; Studinski et al. 2017). Additionally, older juveniles and adult trout will move in search of food when local resources become limited (COSEWIC 2006; Schmetterling 2011; Wilzbach 1985).

2 METHODS

2.1 Westslope Cutthroat Trout

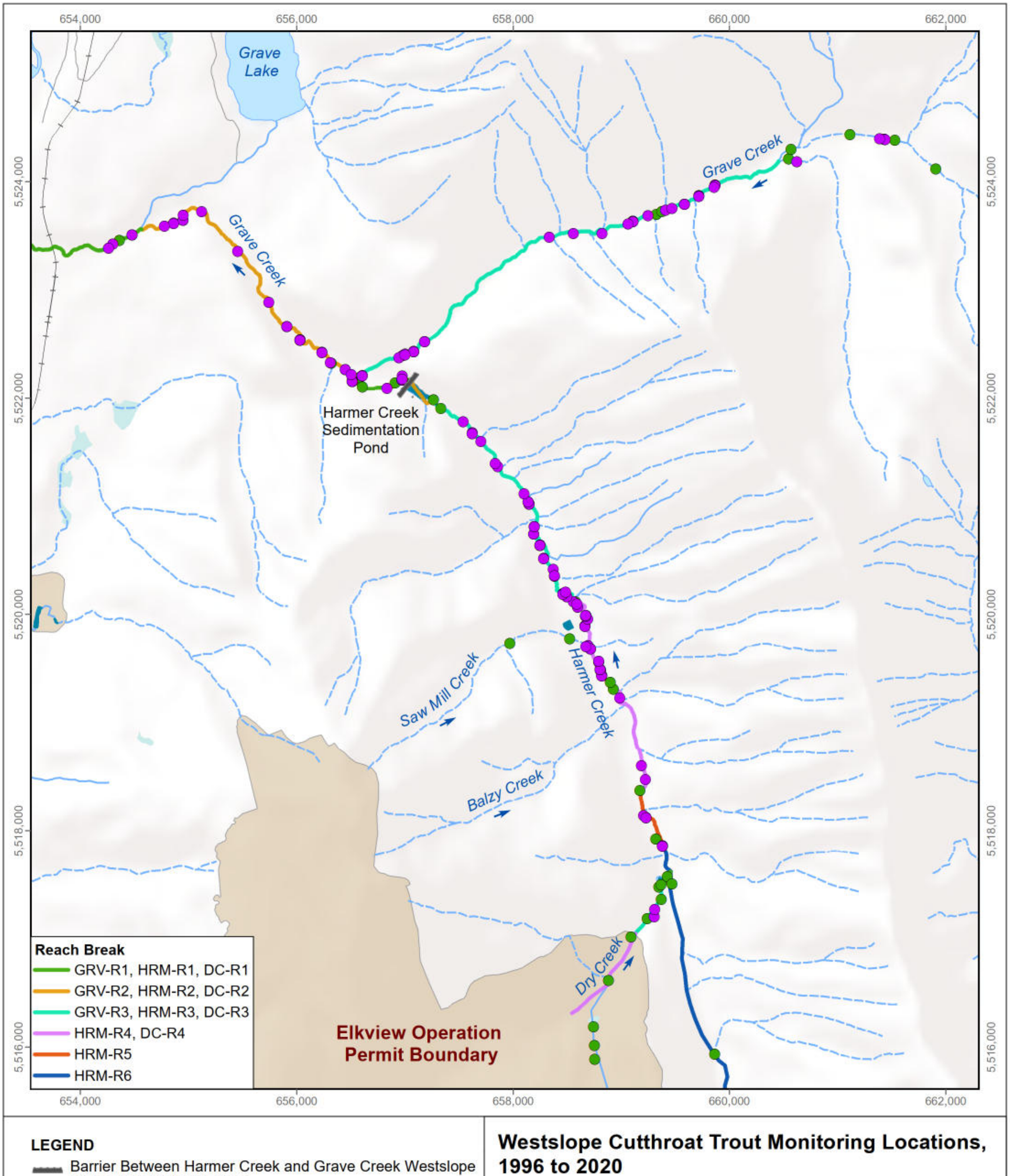
2.1.1 Overview and Data Sources

Weight and length data for Westslope Cutthroat Trout from the Harmer Creek and Grave Creek populations were compiled by Teck Coal and provided to the SMEs. Data were available from backpack electrofishing, boat electrofishing, and angling efforts completed in 1996, 2008, 2013, and 2017 to 2020 to support various monitoring programs and mining and forestry initiatives (e.g., fish salvages; Figure 2.1). Specifically, data sources used in this report included:

- a fish inventory completed in 1996 (Morris et al. 1997);
- a fish and fish habitat assessment completed in 2008 to support the Cedar/Dry Creek Dump Extension (Berdusco 2008);
- fish and fish habitat baseline work completed in 2013 to support the Baldy Ridge Extension Project (Lotic 2015);
- a fish and fish habitat study completed in 2013 to support development of a Westslope Cutthroat Trout population monitoring program (Robinson 2014);
- the Harmer and Grave Creek Westslope Cutthroat Trout Habitat and Population Assessment Report for March 1, 2017 to October 31, 2019 (Cope and Cope 2020)[21];
- data associated with a fish salvage completed on Dry Creek from late September to early October 2017 (Golder 2017); and
- data from monitoring completed in 2020 (Thorley et al. 2022).

Detailed methods regarding fish capture and processing are provided in the individual reports. In September 1996, fishing was completed with a Model 850 Dirigo backpack electrofisher (Morris et al. 1997). Stunned fish were netted and placed in a holding bucket until they could be measured (fork length; mm), weighed (grams [g]), and assessed for sex, maturity, presence of tags or fin clips, and external abnormalities (Morris et al. 1997). In August 2008, backpack electrofishing was completed in an unnamed tributary, Dry Creek, Harmer Creek, and Grave Creek downstream of Harmer Creek (Berdusco 2008). Electrofisher settings were held constant throughout the sampling program and an effort of approximately 500 seconds of active shocking was targeted per sampling location. Captured fish were measured for fork length and weighed

[21] A sub-set of the Westslope Cutthroat Trout from 2018 were also measured, weighed, and sampled for tissue chemistry data; results are reported in the 2017 to 2019 RAEMP report (Minnow 2020).



Westslope Cutthroat Trout Monitoring Locations, 1996 to 2020

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Figure 2.1

(Berdusco 2008). A fish inventory was conducted by backpack electrofishing in June 2013 in Harmer and Dry creeks. At each fish inventory sampling site, a single pass was completed over an approximately 100 metre (m) section of creek, or a length of creek equivalent to approximately 10-times the bankfull width (Lotic 2015). Captured fish were measured (fork length) and weighed. Three pass removal-depletion backpack electrofishing was also completed in Dry, Harmer, and Grave creeks in August 2013 to assess fish densities (Lotic 2015; Robinson 2014). Captured fish were measured, weighed, and assessed for external health. Removal-depletion backpack electrofishing methods were used again in fall 2017 to 2020 (Cope and Cope 2020; Thorley et al. 2022). Captured fish were anaesthetized, measured, weighed, assessed for external abnormalities, and scanned for tags; fish were implanted with a tag if one was not detected. In addition to backpack electrofishing, fishing was also completed by professional anglers in July/August 2017 and August 2018 to support a radio telemetry study (Cope and Cope 2020). Prior to surgical implantation of tags, captured fish were anesthetized, measured, weighed, and assessed for external health (Cope and Cope 2020). Fish were captured from Dry Creek, the Dry Creek Sedimentation Pond, and the South Tributary to Dry Creek in September and October 2017 to support planned in-stream works (Golder 2017). Fish were captured using a backpack or boat electrofisher.[22] Fish were measured (fork length; mm), weighed (g), assessed for external signs of maturity and abnormalities, photographed, and scanned for existing tags. All fish >65 mm fork length were tagged prior to being relocated to Harmer Creek, downstream of Dry Creek (Golder 2017).

2.1.2 Data Analyses

The raw length and weight data obtained from Teck Coal were organized according to year, fish population (i.e., Harmer Creek population or Grave Creek population) and size class. The size classes used herein were selected to align with those used by the broader Harmer Creek Evaluation of Cause Team (2023; see also Thorley et al. 2022), which are largely based on the work of Downs et al. (1997). Fish with fork lengths less than (<) 65 mm (i.e., fry and smaller age-1 juveniles) were excluded from statistical analyses described in the following sections to minimize the influence of low capture efficiency, density-dependence, and measurement errors, the latter of which are more likely to occur when the accuracy of the scale is low relative to a fish's body weight[23] (Johnston and Post 2009; Thompson and Rahel 1996; Wege and Anderson 1978). Consistent with the outcomes of the recent re-evaluation of the

[22] Other fish capture methods, specifically angling and deployment of Gee-style minnow traps and fyke nets, were used as part of the salvage and relocation program; however, no fish were caught using these methods (Golder 2017).

[23] Measurement errors are typically more prevalent when the accuracy of the scale used to weigh a fish is more than plus or minus (±) 1 percent (%) of a fish's body weight (Wege and Anderson 1978).

size-at-maturity information completed by the Harmer Creek Evaluation of Cause Team (2023), Harmer and Grave Westslope Cutthroat Trout with fork lengths ≥170 mm were classified as adults (see Section 1.1.2).

Fulton condition factors (K)[24] were calculated to support comparisons of fish condition among populations; these were tabulated along with summary statistics for fish lengths.[25] The Harmer Creek and Grave Creek populations were included in the tables, along with other populations of Westslope Cutthroat Trout from the Upper Kootenay River watershed (Amos and Wright 2000; Baxter and Hagen 2003; Cope 2020; Cope and Prince 2012; Cope et al. 2016; Morris and Prince 2004; Norecol 1983; Orr and Ings 2021; Prince and Morris 2003). Length and weight data were also plotted to support visual comparisons of fish weights relative to lengths among years. Years of data with sample sizes smaller than n = 4 fish per juvenile or adult grouping were excluded from the plots of weight-at-length.

Statistical comparisons of weight-at-length between areas (i.e., the Harmer Creek and Grave Creek population areas) and years were completed using an Analysis of Covariance (ANCOVA) with $\log_{10}$-transformed body weight as the response, *Area* and *Year* as factors, and $\log_{10}$-transformed fork length as a covariate. To control for seasonal differences, day of the year was also included in the analysis. The modelling proceeded by first including all interactions in the full model. The lack of a significant interaction between *Area* and *Year* would suggest that any difference between the areas was consistent among years. No interactions with the day of year covariate were included and the assumption was made that any seasonal effects were consistent across groups. Significant interactions between *Area* and *Year* or between either of these factors and fork length in the ANCOVA were assessed using $\alpha = 0.05$. If an interaction term was significant, the coefficients of determination (R^2) of the interaction model and non-interaction model were compared to assess whether the slopes were practically significant. If the R^2 was >0.8 and within 0.02 between the two models, then the conclusion was that the interaction model and non-interaction models were practically the same (Environment Canada 2012a) and the ANCOVA proceeded without the interaction. As previously indicated, individuals <65 mm fork length were excluded for the analysis and separate analyses were completed for adults (≥170 mm) and juveniles (<170 mm). Outliers were identified based on Studentized residuals, which were defined for each observation (i.e., each set of length and weight measurements) and were calculated as the difference between the observed versus predicted response (weight) for a given fork length divided by an estimate of the

[24] K = (Weight g/(fork length^3 mm)) * 100,000

[25] Conclusions related to estimated sizes of fry (i.e., age-0 fish) were based on analyses completed by Thorley et al. (2022) (see also Harmer Creek Evaluation of Cause Team 2023).

standard deviation. Observations with Studentized residuals ≥4 were considered outliers and were removed (Environment Canada 2012a). Years with less than four data points were excluded from the ANCOVA.

Post-hoc contrasts comparing among all years of data were completed using a Tukey's Honestly Significant Difference (HSD) test. A magnitude of difference (MOD) between the later and earlier year was calculated as a percentage of the earlier year as:

$$MOD = \frac{MCT_{Year\ 2} - MCT_{Year\ 1}}{MCT_{Year\ 1}} X\ 100\ percent\ (\%)$$

where the measures of central tendency (MCT) were estimated marginal means from the ANCOVA model at the mean fork length for individuals on September 15, consistent with the date used in Thorley et al. (2022). All statistical analyses were completed in R (R Core Development Team 2020).

Because water temperature is one of the key factors influencing the metabolic rates of fishes, components of the temperature evaluation completed by Ecofish Research Ltd. (Ecofish; Hocking et al. 2022) that could explain variation in fish growth were considered in the interpretation of the Westslope Cutthroat Trout length and condition data.

2.2 Aquatic Invertebrates

2.2.1 Overview

Aquatic invertebrates in drift have not been measured directly in Harmer and Grave creeks (or their tributaries). However, benthic invertebrate communities, which represent the source of aquatic invertebrate drift, have been monitored in Harmer and Grave creeks since 2012 (Lotic 2015; Minnow 2014a, 2015, 2018a,b, 2020, 2021). Sampling was also completed in Dry Creek in 2020 (Nupqu and Hemmera 2020).

Positive relationships have been described between benthic invertebrate and drift abundance/composition (Esteban and Marchetti 2004; Rincón and Lobón-Cerviá 1997; Syrjänen et al. 2011; Tonkin and Death 2013), as well as between drift abundance/composition and trout diet (Allan 1981; Elliot 1973; Erös et al. 2012; Esteban and Marchetti 2004; Syrjänen et al. 2011), although some studies did not show such relationships (Naman et al. 2016; Shearer et al. 2003). When invertebrate drift abundance is low, trout will feed directly on benthic invertebrates (Dunham et al. 2000; Fausch et al. 1997; Nakano et al. 1999; Nislow et al. 1998; Zhang and Richardson 2011). In temperate, swift-flowing streams where EPT and dipterans dominate benthic invertebrate communities, these taxa have been identified as important components of salmonid diets (Barbero et al. 2013; Brittain and Eikeland 1988; Fochetti et al. 2003; Leeseberg and Keeley 2014; Nislow et al. 1999; Shearer et al. 2003).

Benthic invertebrate communities in Harmer and Grave creeks are dominated by EPT, as is typical of relatively undisturbed mountain streams in southeastern BC and southwestern Alberta (Minnow 2018a, 2020). Diptera made up a higher proportion of the benthic invertebrate community (relative to EPT taxa) in Dry Creek, based on a small number of samples (i.e., n = 2) collected there in 2020 (Nupqu and Hemmera 2020). The higher proportions of Diptera in the Dry Creek samples from 2020 are not unexpected, based on similar community composition results for other heavily-calcified streams in the Elk River watershed (e.g., Minnow 2022). Historically, EPT taxa along with Diptera, were found in the stomachs of Westslope Cutthroat Trout sampled in the Elk River watershed (Lister and KWL 1980; McDonald and Strosher 1998; Minnow 2004; EVS-Golder 2005; unpublished data from Minnow et al. 2011). Ephemeroptera, in particular, represent both an important energy source to trout in some streams and seasons (Fochetti et al. 2003; Studinski et al. 2017; Wilson et al. 2014) and a sensitive indicator of changes in environmental quality (e.g., Ephemeroptera are sensitive to declining water quality; Clements et al. 2000; Minnow 2017, 2018a; Minnow and Lotic 2018, 2019, 2020; Timpano et al. 2018).

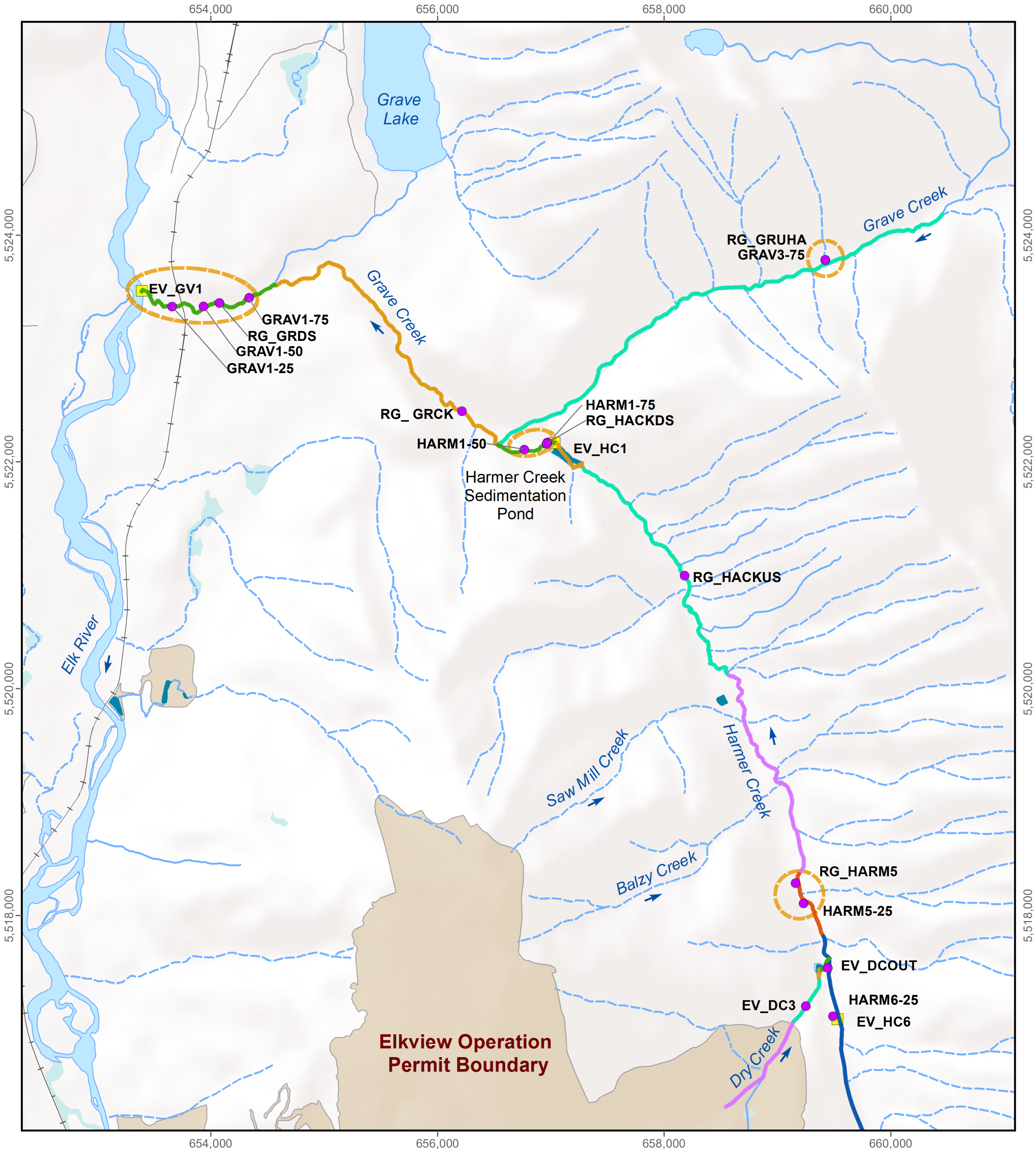
On this basis, it is assumed that a change in food availability sufficient to cause or contribute to reduced recruitment of Westslope Cutthroat Trout in Harmer Creek would be associated with a significant and spatially broad change in benthic invertebrate communities. Therefore, the evaluation of aquatic invertebrate food availability focused on identifying potential changes in benthic invertebrate abundance and community structure in 2016 (i.e., when adults would have started gathering energy stores for the 2017 spawn year) and 2017 to 2019 (i.e., the years of reduced recruitment) compared to earlier years. Also, benthic invertebrate communities in the Harmer Creek population area were compared to benthic invertebrate communities in the Grave Creek population area, which was used as a reference area for the evaluations completed to support the EoC.

2.2.2 Abundance and Community Characteristics

2.2.2.1 Data Sources

Benthic invertebrate abundance and community composition data from the following sources were analyzed to assess whether prey decreased sufficiently to result in food limitations that could have caused or contributed to the reduced recruitment observed in the Harmer Creek Westslope Cutthroat Trout population (Figure 2.2; Table 2.1):

- RAEMP reports and data sets (Minnow 2014a, 2015, 2018a,b, 2020, 2021);
- Special Investigation of the Utility of Periphyton in Future Monitoring Programs in the Elk River Watershed, BC (Minnow 2014b);



LEGEND

- Benthic Invertebrate Community Sampling Location
- Sampling locations treated as replicate stations within the same sampling area for data analysis
- Teck Water Quality Station

Reach Break

- GRV-R1, HRM-R1, DC-R1
- GRV-R2, HRM-R2, DC-R2
- GRV-R3, HRM-R3, DC-R3
- HRM-R4, DC-R4
- HRM-R5
- HRM-R6

Benthic Invertebrate Community Sampling Areas on Dry, Harmer, and Grave Creeks, 2012 to 2020

0 0.75 1.5 3 km

N W E S

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Figure 2.2

Table 2.1: Benthic Invertebrate Community Monitoring Locations in the Harmer Creek and Grave Creek Westslope Cutthroat Trout Population Areas, 2012 to 2020

Westslope Cutthroat Trout Population	Status	Parent Biological Area Code [a]	Biological Area Description	UTMs for Biological Area Code (NAD83, 11U)		Codes Grouped under Parent Code	Data Years and No. of Replicates Per Sampling Event [b]
				Easting	Northing		
Harmer Creek	Reference	HARM6-25	Harmer Creek upstream from Dry Creek	659488	5517110	-	2013 (1), 2014 (1)
	Mine-exposed	EV_DC3	Dry Creek upstream from Dry Creek Sedimentation Pond	659248	5517201	-	2020 (1)
		EV_DCOUT	Dry Creek downstream from Dry Creek Sedimentation Pond	659423	5517558	-	2020 (1)
		RG_HARM5	Harmer Creek downstream from Dry Creek	659158	5518284	-	2014 (1), 2015 (1), 2020 (1)
				659229	5518106	HARM5-25	
		RG_HACKUS	Harmer Creek upstream from Harmer Creek Sedimentation Pond	658180	5520996	-	2012, 2015, 2016, 2018 to 2020 (1 per year)
Grave Creek	Reference	RG_GRUHA	Grave Creek upstream from Harmer Creek	659422	5523781	RG_GRUHA	2012 (1), 2013 (4), 2014 (1), 2015 (1)
				659422	5523781	GRAV3-75	
	Mine-exposed	RG_HACKDS	Harmer Creek downstream from the dam/spillway at the downstream end of Harmer Creek Sedimentation Pond	656969	5522171	RG_HACKDS	2012 (1), 2013 (1), 2014 (4), 2015 (2), 2016 (1), 2017 (1), 2018 to 2020 (5 per year)
				656764	5522109	HARM1-50	
				656962	5522160	HARM1-75	
		RG_ GRCK	Grave Creek downstream from Harmer Creek	656215	5522446	-	2012 (1), 2015 (1)
		RG_GRDS	Grave Creek near the confluence with the Elk River	654077	5523402	RG_GRDS	2012 (1), 2013 (1), 2014 (2), 2015 (1), 2018 to 2020 (1 per year)
				653658	5523369	GRAV1-25	
				653936	5523373	GRAV1-50	
				654338	5523448	GRAV1-75	

Notes: UTMs = Universal Transverse Mercator coordinates; NAD = North American Datum; No. = number; - = no data/not applicable.

[a] The "Parent Biological Area Code" will be used for all areas grouped under the parent code (e.g., RG_GRUHA will be used to refer to RG_GRUHA and GRAV3-75).

[b] Number of replicate samples collected is in brackets for each data collection year.

- Baldy Ridge Extension Project – Fish and Fish Habitat Baseline Assessment (Lotic 2015);
- Preliminary (2014) Evaluation of Calcite Effects on Benthic Invertebrate Communities and Periphyton Productivity (Minnow 2015); and
- Dry Creek Aquatic Health Baseline Study – Field Summary Report (Nupqu and Hemmera 2020).

Benthic invertebrate community monitoring occurred in September of each year and sampling methods were consistent among projects. The number of replicates collected per biological sampling area ranged from n = 1 to n = 5 (Table 2.1), depending on the year and location. Benthic invertebrate sampling followed the Canadian Aquatic Biomonitoring Network (CABIN) method, which involved three-minute travelling kick sampling in riffle habitats using a net with a triangular aperture measuring 36 centimetres (cm) per side and mesh having 400 micrometre (µm) openings (Environment Canada 2012b). During sampling, the field technician moved across the stream channel (from bank to bank, depending on stream depth and width) in an upstream direction. The net was held immediately downstream from the technician's feet and the detritus and invertebrates disturbed from the substrate were passively collected in the kick-net by the stream current. After three minutes of sampling time, the technician returned to the stream bank with the sample. The kick-net was rinsed with water to move debris and invertebrates into the collection cup at the bottom of the net. The collection cup was then removed, and the contents poured into a labelled plastic jar and preserved to a level of 10% buffered formalin in ambient water.

Benthic invertebrate community samples were sent to Cordillera Consulting in Summerland, BC (Lotic 2015, Minnow 2014a, 2015, 2018a,b, 2020, 2021) or Biologica Environmental Services Ltd. in Victoria, BC (Nupqu and Hemmera 2020) for sorting and taxonomic identification. Organisms were identified to the lowest practical level (LPL) (typically genus or species).

2.2.2.2 Data Analyses

Data for benthic invertebrate sampling locations that were in close proximity to one another and considered representative of similar habitat (i.e., within the same reach segment and without intervening tributary inflows) were treated as replicate stations within a "Parent Biological Area" (Figure 2.2; Table 2.1). For example, samples collected from HARM5-25 in 2014 and 2015 and RG_HARM5 in 2020 were combined under the RG_HARM5 "Parent Biological Area" code and used to support the assessment of changes in benthic invertebrate abundance and community composition over time at that location (Figure 2.2; Table 2.1; see below).

An overall analysis of variance (ANOVA) with factors *Year*, *Area*, and *Year* × *Area* was fit to test for differences in the following endpoints over time (2012 to 2020) at each biological monitoring area:

- total benthic invertebrate abundance;
- abundances of major taxonomic groupings, including combined EPT and Ephemeroptera, Plecoptera, Trichoptera, and Diptera; and
- proportions (also known as "relative abundance") of major taxonomic groupings, including combined EPT and Ephemeroptera, Plecoptera, Trichoptera, and Diptera.

The best transformation for each endpoint was chosen as the transformation for which a Shapiro-Wilk's test on the residuals gave the highest p-value (i.e., most normally distributed). If there was a significant *Year* term, the variability within years and areas from the full model was used to test for significant differences between all pairwise comparisons of year for each area (i.e., is the difference between year *i* and year *j* greater than would be expected given the variability within areas for all stations for which we have replicates). This assumes the variability to be consistent among areas and years but allows for comparisons between years without replicates. Significance of the pairwise comparisons was assessed with an α of 0.05 in a Tukey's HSD test, which corrects for the number of comparisons.

For each year, a percent MOD from the base year (i.e., first year with data) was calculated as:

$$\frac{Year_i - Base\ Year}{Pooled\ SD}$$

Where SD was the standard deviation and the significant difference between 2020 and previous years was assessed. All statistics were conducted in R (R Core Development Team 2020).

The abundance and community composition data were also plotted to visually depict results. To assist in interpreting magnitudes of change over time, values were presented relative to endpoint-specific regional reference area normal ranges from the RAEMP (Minnow 2020). Each reference area normal range represents the 2.5^{th} to 97.5^{th} percentiles of data collected from reference areas between 2012 and 2019 (Minnow 2020). Abundance and community composition data for both the Harmer Creek and Grave Creek population areas were included on the plots to support visual identification of patterns indicative of changes occurring in the Harmer Creek population area, but not the Grave Creek population area. Statistical comparisons of benthic invertebrate community endpoints between the Harmer Creek and Grave Creek population areas could not be made due to the following (Figure 2.2; Table 2.1):

- poor within-year replication for areas other than RG_HACKDS (2017 to 2020);

- EV_DC3 and EV_DCOUT (Harmer Creek population area) having only one year of data collection (and only one replicate per year) ; and
- high interannual variability among areas, based on data for areas where more than one sample was collected.

2.3 Terrestrial Invertebrates

2.3.1 Overview

The overall mean proportion of terrestrial prey abundance in salmonid diets is typically low (i.e., 17%; based on a review by Syrjänen et al. 2011). However, terrestrial invertebrates can sometimes represent a large proportion of the dietary abundance or biomass of salmonids (Albertson et al. 2018; Courtwright and May 2013; Li et al. 2016; Sweka and Hartman 2008), which can positively influence fish growth or condition (Erös et al. 2012; Studinski et al. 2017; Sweka and Hartman 2008). Also, the relative proportions of aquatic versus terrestrial prey in trout diets can vary widely among closely located streams or among years (Wilson et al. 2014; Sepulveda 2017; Studinski et al. 2017).

Relative consumption of terrestrial versus aquatic prey is sometimes a simple reflection of relative availability in drift (Esteban and Marchetti 2004; Wilson et al. 2014). In other cases, the relative abundance or biomass of terrestrial invertebrates in trout diet exceeds relative abundance in drift, suggesting dietary selectivity (Courtwright and May 2013; Kraus et al. 2016). This may be because terrestrial invertebrates are often larger than aquatic prey, making terrestrial prey conspicuous targets and energetically profitable relative to capture effort (Baxter et al. 2005; Naman et al. 2016). Consumption of terrestrial invertebrates is likely most important in streams when and where benthic invertebrate biomass is low (Albertson et al. 2018; Wilson et al. 2014) or aquatic invertebrate drift density is low (Kraus et al. 2016). Aquatic invertebrate drift density tends to decline from spring to fall in temperate streams (Leeseberg and Keeley 2014; Nakano et al. 1999; Rincón and Lobón-Cerviá 1997) as stream flows decline (Caldwell et al. 2018). By comparison, terrestrial invertebrate drift abundance and biomass (Erös et al. 2012; Romaniszyn et al. 2007; Thayer 2016) and consumption by trout (Li et al. 2016; Studinski et al. 2017; Thayer 2016) tend to peak in summer.

Terrestrial invertebrate inputs to drift have not been measured in the Elk River watershed. However, inputs of terrestrial invertebrates to streams are strongly linked to the amount and type of riparian vegetation (Albertson et al. 2018; Allan et al. 2003; Romero et al. 2005; Wilson et al. 2014; Wipfli 1997) and surrounding land use (Edwards and Huryn 1996; Erös et al. 2012). In the context of the Harmer Creek Westslope Cutthroat trout population, it is reasonable to expect that a large enough change in terrestrial invertebrate inputs to affect recruitment of Westslope Cutthroat Trout would be unlikely unless associated with spatially broad changes in riparian habitat amounts and/or land use after 2016. Teck Coal tracks riparian habitat and land use patterns to support the Tributary Management Plan (Minnow 2016; Teck Coal 2020). Total riparian habitat and mine-disturbance footprint areas within the Harmer and Grave watershed were compared between 2016 and 2020. Changes in the total area of riparian habitat that were on the order of 1 hectare (ha) or more were evaluated in greater detail to determine the specific year(s) in which the changes occurred within the 2016 to 2020 period. This threshold is based on the sizes of treatment areas, and the ability to detect statistically significant differences in terrestrial invertebrate inputs to trout-containing streams, for a field study of the effects of riparian vegetation removal and cattle grazing on trout diets (Saunders and Fausch 2017). In the context of food for fish, the specific location of disturbances along the stream is relatively unimportant. The drift structure at a given place in a stream depends not only on local production, but also on upstream distant areas (e.g., terrestrial invertebrates falling or washing into streams in a headwater may be consumed by fish farther downstream; Wipfli and Gregovich 2002).

2.3.2 Catchment Areas

Strictly speaking, "watershed" refers to the high ground or ridge that divides waters flowing to adjacent river systems, whereas terms such as "catchment", "basin", and "drainage area" refer to the area bounded by the watershed. However, these terms are often used interchangeably, as is usually the case when referring to the Elk River watershed. Likewise, this document uses the word "watershed" interchangeably with those referring to catchment area, so the term "watershed boundary" is used to refer to the line dividing adjacent catchments.

The catchment areas for each tributary and the Harmer and Grave main stems were determined using the Freshwater Atlas, which replaces the Corporate Watershed Base (CWB) data set (formerly known as the Terrain Resource Information Management [TRIM] Watershed Atlas; Carver and Gray 2009; Province of British Columbia 2021). The Freshwater Atlas defines watersheds and provides an associated stream and lake network. The CWB data set adds functionality to TRIM 1:20,000 digital topographic base map data by providing a connected feature-coded stream network, hydrographic information, and associated watershed boundaries. The total catchment area (in square kilometres [km^2]) from the CWB data set is used for calculating disturbance areas associated with mining, forestry, and other anthropogenic activities, as applicable.

2.3.3 Riparian Habitat Area

A modified version of the riparian habitat assessment methods from the Baldy Ridge Project (Golder 2015) was used to quantify riparian habitat areas within each catchment area presented in the matrices of this report. Riparian areas are broadly defined as wet forest and flood[26] ecosystems that interact with a waterbody or watercourse and represent low-lying areas that may be periodically inundated with water. They represent a connection between the surrounding terrestrial and aquatic environments and are typically described based on the following features: ecosystem type; adjacency and connectedness to waterbodies or watercourses; extent relative to their distance from waterbodies or watercourses, and elevation.

Riparian habitat amount (expressed as total km^2) was calculated using both the hydrologic and stream adjacency approaches, consistent with Teck Coal's Tributary Management Plan (Teck Coal 2020). Following these approaches, which are described in the following sub-sections, riparian habitats are defined as flood and wet forest ecosystems classes that intersect a buffer area around streams and waterbodies. This includes but is not limited to tributaries, rivers, ponds, lakes, and wetlands. The applied buffer is variable, depending on the stream order, and by the size of the waterbody or watercourse. Additionally, flood and wet forest ecosystems outside of the stream adjacency buffers are not included as riparian areas, and ecosystems within the buffer that are not defined as riparian ecosystems are not considered riparian areas.

Ecosystem classifications were identified using Teck Coal's Terrestrial Ecosystem Mapping (TEM) database, where possible. In locations where current TEM or backcasted TEM products were not available the default option was to use the provincial Predictive Ecosystem Mapping data set. Modelling of riparian areas relied on the Aquatic Data Integration Tool (ADIT) data set, which was built off of the Tributary Management Plan data set and uses an updated water network. Riparian areas were represented as an additional attribute within Teck Coal's TEM products.

2.3.3.1 Hydrologic Approach

The hydrologic approach defined riparian habitat as wet and flooded forest ecosystem classes (i.e., site series 110, 111, 111x, 112x [i.e., wet forest] where soil moisture regime is 5 or 6 and flooded low bench tall shrub [Fl], high bench floodplain [Fh], flooded middle bench deciduous forest [Fm], sub-irrigated flood fringe [Ff], and active channel flood [Fa] habitat types [MacKillop et al. 2018]) that intersected a buffer area around streams and waterbodies.

[26] The flood class includes conifer-dominated floodplains and herbaceous-dominated ecosystems, as examples.

Buffers were 200 m for stream orders 7 and 8, 100 m for stream orders 5 and 6, 50 m for stream orders 3 and 4 and all other waterbodies, and no buffer for stream orders 1 and 2 (i.e., the stream must intersect the wet forest or floodplain). Deciduous floodplain and wet forest polygons outside the buffer were not included. Similarly, ecosystems within the buffer that were not wet forests or floodplains were not considered riparian habitat using the hydrologic approach.

The hydrologic approach was selected to capture riparian habitat that is not necessarily intersecting a watercourse but is still defined as riparian habitat because it exists in areas that may be periodically inundated when water levels are high, and ecological connectivity with the watercourse is thereby maintained.

2.3.3.2 Stream Adjacency Approach

The stream adjacency approach applied a variable width buffer to streams, ponds, and lakes to define riparian habitat, as follows:

- stream orders 7 and 8 = 50 m;
- stream orders 4, 5 and 6, waterbodies and wetlands = 30 m;
- stream order 3 = 20 m; and
- stream orders 1 and 2 = 10 m.

High-elevation streams with Biogeoclimatic Ecosystem Classifications (BEC) of Englemann Spruce- Subalpine Fir (e.g., ESSF dkp, ESSF dkw, ESSF wpm, ESSF wmw) and Undifferentiated Interior Mountain (IMAun) were excluded from the analysis because they are not identified as containing the climatic, physical, functional, and structural attributes to support riparian-dependent vegetation and wildlife species. Such areas are sub-alpine to alpine ecosystems with extremely harsh conditions that hamper survival of vegetation and, specifically, riparian assemblages. Riparian habitats near clear-cuts were assumed to be vegetated. This is because Canfor holds the timber rights in the Grave Creek watershed and is required to operate in accordance with regulations (Tschaplinski and Pike 2010) and best management practices implemented by industry to maintain natural vegetation in riparian habitat (BC Ministry of Forests and BC Environment 1995).

The adjacency approach was selected to capture habitat that plays a role in riparian and aquatic health or function (e.g., shading, streamside deadfall), but that is not necessarily identified as a riparian ecosystem in the BEC system.

2.3.4 Disturbance Area

The disturbance areas were determined from three data sets, two of which were provided by Golder Associates (Golder) and were developed at regional scales to support environmental assessments for Teck Coal's projects in the Elk River watershed. The third data set used for disturbance was Teck Coal's in-house disturbance Geographic Information System (GIS) layer which tracks cumulative mine-related disturbance for Teck Coal's mines in the Elk River watershed. Total disturbance prior to September 2016 was calculated and represents conditions prior to the period of interest for reduced recruitment. The year 2016 was selected based on the assumption that changes in habitat areas and subsequent reductions in terrestrial invertebrate contributions to drift could have affected adult spawners starting in fall 2016, as well as potential recruits spawned in 2017 to 2019. Total disturbance areas were also calculated for 2020, to support comparisons of before (2016) and after (2020) the spawn years associated with reduced recruitment.

2.3.5 Terrestrial Data Evaluation

Total watershed areas for the Dry Creek and Harmer Creek upstream of Harmer Creek Sedimentation Pond (i.e., the Harmer Creek population area) and Grave Creek and Harmer Creek downstream from the Harmer Creek Sedimentation Pond (Grave Creek population area) were tabulated for 2016 and 2020. Total riparian and disturbance areas were also included in the table. Differences between years were computed and expressed as a percentage relative to 2016. The percent changes in riparian and disturbance areas were used as a proxy or surrogate measure of changes in the quantity or quality of terrestrial invertebrates as a food source. Again, habitat changes on the order of 1 ha or more were evaluated in greater detail to determine the specific year(s) in which the changes occurred within the 2016 to 2020 period to identify the timing of potential changes in the quantity or quality of terrestrial invertebrates in drift.

3 RESULTS

3.1 Westslope Cutthroat Trout

3.1.1 Fry and Juvenile Westslope Cutthroat Trout

Body length data for fry would be the most direct indicator of growth and energy storage for fish entering their first winter season (Biro et al. 2005; Thompson et al. 1991) and would inform conclusions about size-selective overwintering mortality (Coleman and Fausch 2006; Meyer and Griffith 1997). However, capture efficiency is low for fish that small (Thompson and Rahel 1996) and few data were available to support annual estimates of fork length for fry captured from the Harmer Creek and Grave Creek population areas. Regardless, the analyses completed by other SMEs (Thorley et al. 2022; Thorley and Branton 2023) using the limited data set for fry indicated that individuals from the Harmer Creek population were smaller (i.e., shorter), on average, than fry from the Grave Creek population area in 2017 and 2018.[27] The results of these analyses also indicated fry from the Harmer Creek population area were likely below a minimum size threshold (i.e., 30 to 35 mm) for overwinter survival (Coleman and Fausch 2006) after 2017 (Harmer Creek Evaluation of Cause Team 2023; Thorley et al. 2022). It is therefore possible that factors related to growth of fry and size-selective overwintering mortality could have contributed to reduced recruitment (Harmer Creek Evaluation of Cause Team 2023; Thorley and Branton 2023). However, because factors other than food availability can influence fish growth, other lines of evidence related to food availability (Sections 3.2 and 3.3) need to be considered before it can be ruled in or out as a causal or contributing factor in the reduced recruitment for the 2017 to 2019 spawning year cohorts.

Condition of juvenile fish (age-1 or age-2 fish up to 170 mm fork length; Section 1.1.2) captured in fall of 2017, 2018, and 2019 was evaluated as another line of evidence related to energy stores and possible food limitations. Data for juveniles were used as proxies for condition of fry in those years (i.e., data for juvenile individuals captured in fall were considered indicative of environmental conditions encountered by fry of the same year). Overall, it was anticipated that reduced weight-at-length for any age grouping of Westslope Cutthroat Trout captured from the Harmer Creek population area during the period of interest compared to previous years or the Grave Creek population may be evidence for starvation and, potentially, food limitations.

[27] No field-collected fork length data were available for age-0 fish from the Harmer Creek population in 2019; however, modelled fork lengths for age-0 fish were lower relative to those from the Grave Creek population area (Thorley and Branton 2023).

Fulton condition factors and fork lengths of juvenile Westslope Cutthroat Trout captured from the Harmer Creek population area were similar to condition factors for juvenile fish captured from the Grave Creek population area in each monitoring year, including the years with reduced recruitment (Table 3.1; Appendix Table A.1). Additionally, Fulton condition factors and fork lengths for juvenile fish from the Harmer Creek population (and Grave Creek population) were consistent among years. Condition factors were also comparable to condition factors reported for juvenile Westslope Cutthroat Trout captured from the Upper Fording River between 1983 and 2019 (Table 3.1). However, it is recognized that the sample sizes for juvenile fish from the Harmer Creek population were low in 2019 ($n = 3$) and 2020 ($n = 5$) and that no age-1 fish were captured in those years (i.e., data are for age-2+ fish) (Cope and Cope 2020; Thorley et al. 2022). Therefore, there is more uncertainty in the comparisons for juvenile fish for those years (Appendix Table A.1). Additionally, no data were available to assess the length or condition of fish that did not survive until the first fall following post-emergence (i.e., when they would be first sampled at age-1s). Therefore, it is unclear whether mortalities would have shown pronounced growth effects that were not observed in surviving fish (Keeley 2001).

Juvenile Westslope Cutthroat Trout weight-at-length was not significantly different ($p = 0.724$) between the Harmer Creek and Grave Creek populations in 2008, 2013, 2017, 2018, or 2020 (Figure 3.1; Appendix Figure A.1; Appendix Table A.2).[28] Mean weights-at-length for juvenile fish from both the Harmer Creek and Grave Creek populations were slightly (3.9%; $p = 0.023$) lower in 2018 compared to 2017 but comparable to 2008 and 2013 (Appendix Figures A.1 and A.2; Appendix Tables A.3 and A.4). Mean weights-at-length for juvenile fish from the Harmer and Grave Creek populations were slightly higher in 2020 relative to 2017 (5.8%; $p = 0.024$) and 2018 (10%; $p < 0.001$) and 15% higher in 2020 relative to 2013 (i.e., prior to the period of reduced recruitment; $p < 0.001$; Appendix Figures A.1 and A.2; Appendix Tables A.3 and A.4). Overall, the results of the comparisons indicate that juvenile Westslope Cutthroat Trout captured in 2017 and 2018 (i.e., the year with the greatest probability of recruitment failure) did not have unusually low body condition.[29] These findings are supported by the comparison of condition factors (Table 3.1).

Because factors other than food availability can affect fish growth/size and energy stores/condition, the smaller estimated sizes (i.e., fork lengths) of fry from the Harmer Creek

[28] The 2019 data for the Harmer Creek population (i.e., the year in which the 2018 spawning cohort would be monitored for the first time) could not be included in the comparisons due to the small sample size for that year (i.e., $n = 3$).

[29] This was considered in the context of the critical effect size of 10% for fish condition that is typical of EEM (Environment Canada 2012a).

Table 3.1: Summary of Fulton Condition Factor (K) and Fork Length for Westslope Cutthroat Trout Approximating Juvenile Size Ranges of the Harmer Creek and Grave Creek Populations Compared to Upper Fording River

Location	Year	Fulton K				Fork Length (mm)	
		Average	Min	Max	N	Average	Range
Upper Fording River	1983 [a,b]	1.15	0.63	1.63	-	-	-
	1999 [a,c]	1.18	0.93	1.79	95	-	74 to 250
	2013 [a]	1.13	0.96	1.31	103	120	62 to 223
	2014 [a]	1.18	0.79	1.65	183	128	65 to 244
	2015 [a]	1.07	0.70	1.63	313	117	65 to 260
	2017 [d,e]	1.29	0.52	2.00	325	126	61 to 259
	2019 [e]	1.13	0.66	1.56	195	120	60 to 233
Grave Creek	2008 [f]	1.18	1.00	1.29	5	95.8	69 to 146
	2013 [g,h]	1.15	1.00	1.27	6	125	100 to 148
	2017 [i,j]	1.13	0.77	1.65	78	109	66 to 148
	2018 [i]	1.08	0.92	1.31	83	107	67 to 145
	2019 [i]	1.12	0.94	1.33	56	113	66 to 148
	2020 [k]	1.20	0.77	2.63	37	110	77 to 143
Harmer Creek	2008 [f]	1.24	1.13	1.40	11	107	89 to 128
	2013 [g,h]	1.13	0.95	1.35	8	112	82 to 142
	2017 i[j,k]	1.13	0.91	1.61	96	118	69 to 149
	2018 [i]	1.08	0.84	1.26	20	117	66 to 149
	2019 [i]	1.19	1.19	1.19	1	143	143
	2020 [l]	1.17	1.09	1.23	4	122	101 to 140

Notes: min = minimum; max = maximum; N = number; mm = millimetres; - = not reported.
[a] As presented in Cope et al. (2016).
[b] Norecol 1983.
[c] Amos and Wright 2000.
[d] Measurement errors for an unknown number of fish occurred in 2017 because a weigh scale malfunctioned. Exclusion of all K values greater than 2 (n = 88) eliminated obvious outliers but the data set may still be biased by measurement errors.
[e] Cope 2020.
[f] Berdusco 2008.
[g] Lotic 2015.
[h] Robinson 2014.
[i] Cope and Cope 2020.
[j] Golder 2017.
[k] One outlier was removed prior to calculation of summary statistics.
[l] Thorley et al. 2021.

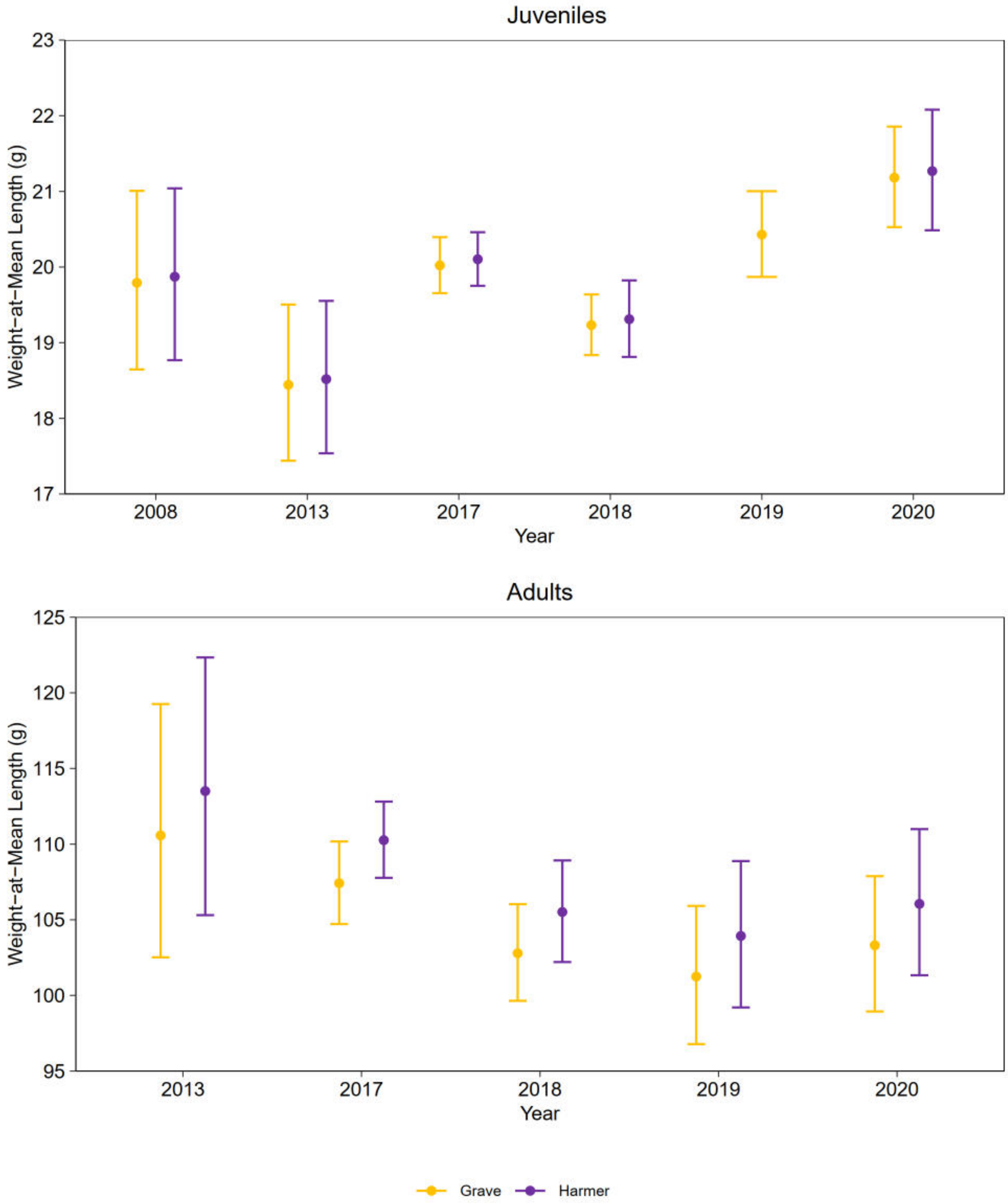

Figure 3.1: Estimated Weight-at-Mean Length for Juvenile and Adult Westslope Cutthroat Trout from the Harmer Creek and Grave Creek Populations, 2008 to 2020

Notes: Comparisons were made using an Analysis of Covariance (ANCOVA) with mean weight estimated for individuals at mean fork lengths for each group (juveniles or adults) on September 15th of the respective year. Three adults and six juvenile individuals (2017 and 2020) were removed as outliers in the analysis (based on Studentized residuals greater than or equal to [≥] 4). Data for Harmer Creek juveniles captured in 2019 were not plotted/included in the ANCOVA due to the small sample size (n = 3) for that year.

population area and subtle interannual differences are not considered stand-alone evidence for food limitations. For example, colder water temperatures and the metabolic costs of responding to other environmental stressors (e.g., poor water quality) are known to reduce growth rates in salmonids (Coleman and Fausch 2007a; Marr et al. 1996). Colder water temperatures in the weeks following swim-up, in particular, can result in lower energy stores and poor overwinter survival for age-0 fish (Coleman and Fausch 2007a). Harmer and Grave creeks are cold water systems characterized by low summer peak temperatures and low growing season ATUs; for this reason, emergence may occur into October (see Chapter 3 of the EoC report [Harmer Creek Evaluation of Cause Team 2023]). In 2018 and 2019, ATU throughout most of Harmer Creek were identified as being marginally suitable or unsuitable for recruitment (Hocking et al. 2022) and potentially explained 34% of the reduced recruitment observed from 2017 to 2019 (Thorley and Branton 2023). Therefore, without sufficient time for adequate feeding and growth prior to the onset of winter, there could have been potential growth effects in the absence of food limitations (see Sections 3.2 and 3.3). The roles of other stressors (e.g., water and sediment quality) that could have affected growth and condition of Westslope Cutthroat Trout in the Harmer Creek population area are assessed in detail in other SME reports (de Bruyn et al. 2022; Warner and de Bruyn 2022; Wiebe et al. 2022).

3.1.2 Adult Westslope Cutthroat Trout

Condition factors of adult Westslope Cutthroat Trout captured from the Harmer Creek population area were similar to condition factors for adult fish captured from the Grave Creek population area in each monitoring year, including years relevant to the reported reduction in recruitment (Table 3.2; Appendix Table A.1). When evaluated over time, condition factors for adult Westslope Cutthroat Trout from the Harmer Creek population were consistent among years, including those associated with the period of interest (Table 3.2; Appendix Table A.1). Had food limitations for adult spawners been a causal or contributing factor in the reduced recruitment for the Harmer Creek Westslope Cutthroat Trout population, a reduction in adult body condition would have been expected potentially as early as 2016 or 2017 (leading into egg development for spawning in 2017 or 2018).

Weight-at-length for adult Westslope Cutthroat Trout from the Harmer Creek population was greater relative to the Grave Creek population ($p = 0.043$) across years (i.e., in 2013 and from 2017 to 2020; Figure 3.1; Appendix Figure A.3; Appendix Table A.2). Samples sizes were sufficient to support comparisons among years, including in 2019 when too few juveniles were captured in Harmer Creek for comparisons between the two populations. The within-year comparisons of weight-at-length between the two populations indicate that there were no factors uniquely and adversely affecting fish condition in the Harmer Creek population area, but not the

Table 3.2: Summary of Fulton Condition Factor (K) and Fork Length For Upper Kootenay River Populations of Adult Westslope Cutthroat Trout Captured Using Similar Methods

Location	Year	Fulton K				Fork Length (mm)	
		Average	Min	Max	N	Average	Range
Upper Bull River	2010 [a,b]	1.18	0.89	2.14	65	316	230 to 433
Elk River	2000 to 2001 [a,c]	1.44	1.17	1.84	40	374	325 to 422
St. Mary River	2001 to 2002 [a,d]	1.28	1.08	1.89	40	396	340 to 430
Wigwam River	2001 [a,e]	1.14	0.95	1.40	31	393	340 to 450
Upper Fording River	2012 [f]	1.41	1.10	1.80	205	301	202 to 485
	2013 [f]	1.39	0.91	2.58	227	270	201 to 460
	2014 [f]	1.54	0.91	2.33	236	282	201 to 485
Grave Creek	2008 [g]	1.50	1.50	1.50	1	177	-
	2013 [h,i]	1.36	1.26	1.45	4	193	174 to 205
	2017 [j,k]	1.29	0.948	1.67	70	205	171 to 383
	2018 [j]	1.21	1.01	1.40	35	207	170 to 251
	2019 [j]	1.18	1.04	1.36	13	188	173 to 228
	2020 [m]	1.20	0.955	1.50	15	209	172 to 262
Harmer Creek	1996 [n]	1.36	1.36	1.36	1	245	245 to 245
	2013 [h,i]	1.30	1.24	1.35	4	198	183 to 209
	2017 [j,k]	1.31	1.03	1.89	84	203	170 to 320
	2018 [j]	1.27	1.10	1.40	25	203	170 to 282
	2019 [j]	1.20	0.928	1.46	9	207	172 to 243
	2020 [m]	1.27	0.995	1.47	9	233	185 to 282

Notes: "-" not applicable; min = minimum; max = maximum; N = number; mm = millimetres.
[a] As presented in Cope et al. (2016).
[b] Cope and Prince 2012.
[c] Prince and Morris 2003.
[d] Morris and Prince 2004.
[e] Baxter and Hagen 2003.
[f] As presented in Orr and Ings (2021).
[g] Berdusco 2008.
[h] Lotic 2015.
[i] Robinson 2014.
[j] Cope and Cope 2020.
[k] Golder 2017.
[l] Outliers were removed prior to calculation of summary statistics.
[m] Thorley et al. 2022.
[n] Morris et al. 1997.

Grave Creek population area, that could explain the reduced recruitment in the former. Therefore, it does not appear that the reduced recruitment in the Harmer Creek population was caused by a reduction in energy stores available for investment in reproduction. Weight-at-length for adults in the Harmer Creek and Grave Creek populations in 2018 were slightly reduced (by 4.3%; $p = 0.046$) compared to 2017 but not different from 2013, 2019, or 2020 (Figure 3.1; Appendix Figures A.2 and A.3; Appendix Tables A.3 and A.4). The ANCOVA results support conclusions from the comparison of condition factors (Table 3.2), which are that adult Westslope Cutthroat Trout captured from the Harmer Creek population area in 2017 to 2020 had similar body condition to fish captured in previous years and from other Upper Kootenay River populations.

3.2 Aquatic Invertebrates

Total benthic invertebrate abundances reported for the three-minute CABIN kick samples collected from within the Harmer Creek and Grave Creek population areas varied among areas and years; however, there was broad overlap in total abundances between the two population areas. In both population areas, total benthic invertebrate abundances were within or above the regional reference area normal range, historically and within the period of interest for reduced recruitment (Figure 3.2; Appendix Table A.5). As indicated in Section 2.2.2, the reference area normal ranges were calculated from a large data set representing reference creeks, many of which also support Westslope Cutthroat Trout and other fish species. Limited data (i.e., one sample each from RG_DC3 and RG_DCOUT) indicated relatively low total benthic invertebrate abundance in Dry Creek (Harmer Creek population area) in 2020 (Figure 3.2). However, total benthic invertebrate abundances in Dry Creek in 2020 were within the reference area normal range and comparable to 2013 data for the reference area on Harmer Creek (HARM6_25) upstream from Dry Creek (Figures 2.2 and 3.2; Appendix Table A.5). Mesohabitats in Dry Creek are predominantly step-pools and short runs (Golder 2017; Lotic 2015; Nupqu and Hemmera 2020), whereas riffles, which are preferred habitats for many benthic invertebrate taxa (Brown and Brussock 1991; Logan and Brooker 1983), are more common throughout Harmer Creek (Cope and Cope 2020). Additionally, habitats in Dry Creek were impacted by extensive calcification and formation of calcite terraces in the years prior to (e.g., Lotic 2015) and during (e.g., Nupqu and Hemmera 2020) the period of interest for reduced recruitment. It is considered likely that mesohabitat conditions and the presence of calcite in Dry Creek contributed to lower total benthic invertebrate abundances (relative to other monitoring areas on Harmer and Grave creeks) in years prior to and during the period of reduced recruitment (i.e., the 2020 data for Dry Creek are unlikely to represent a scenario unique to the period of reduced recruitment).

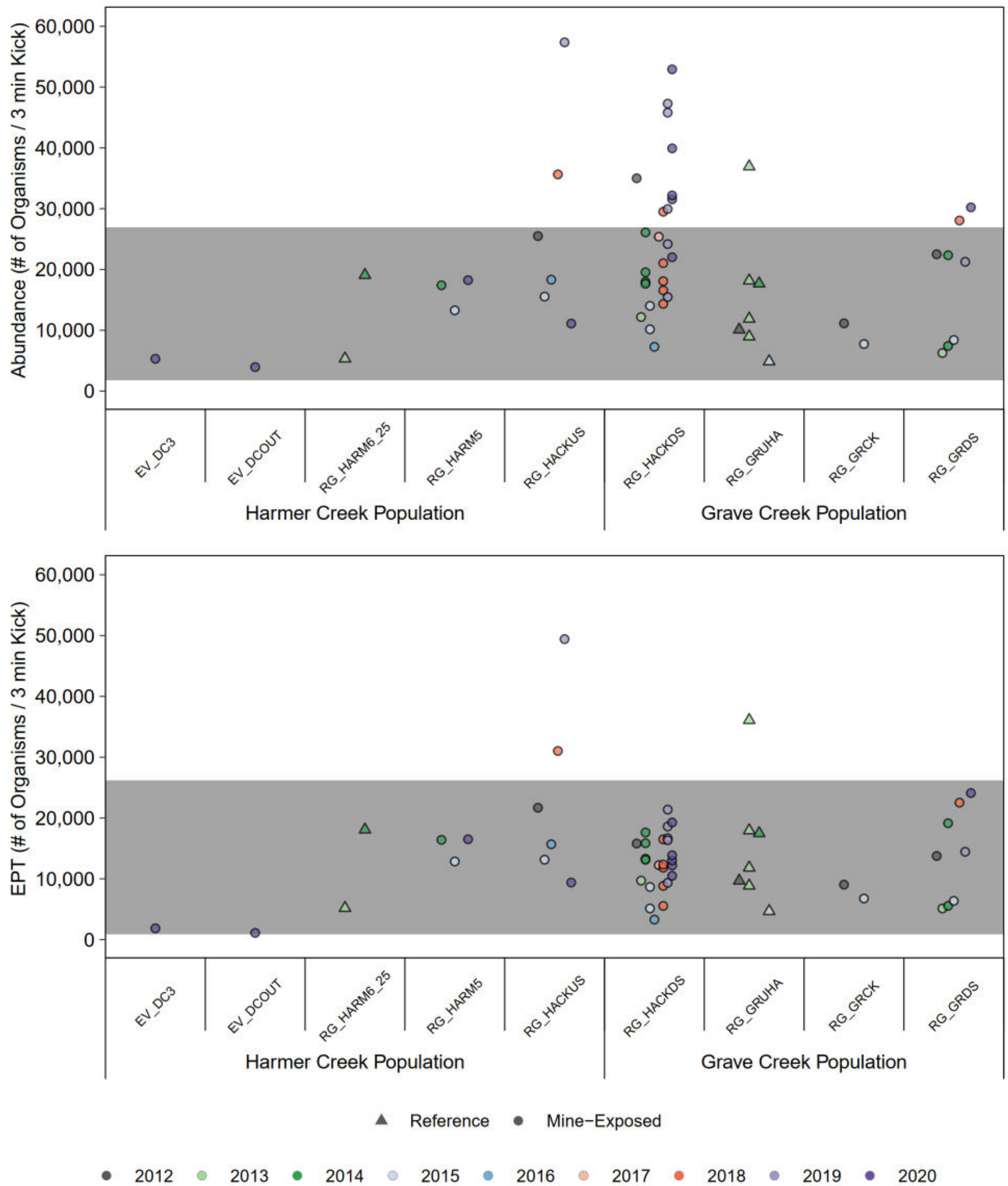

Figure 3.2: Benthic Invertebrate Abundance in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

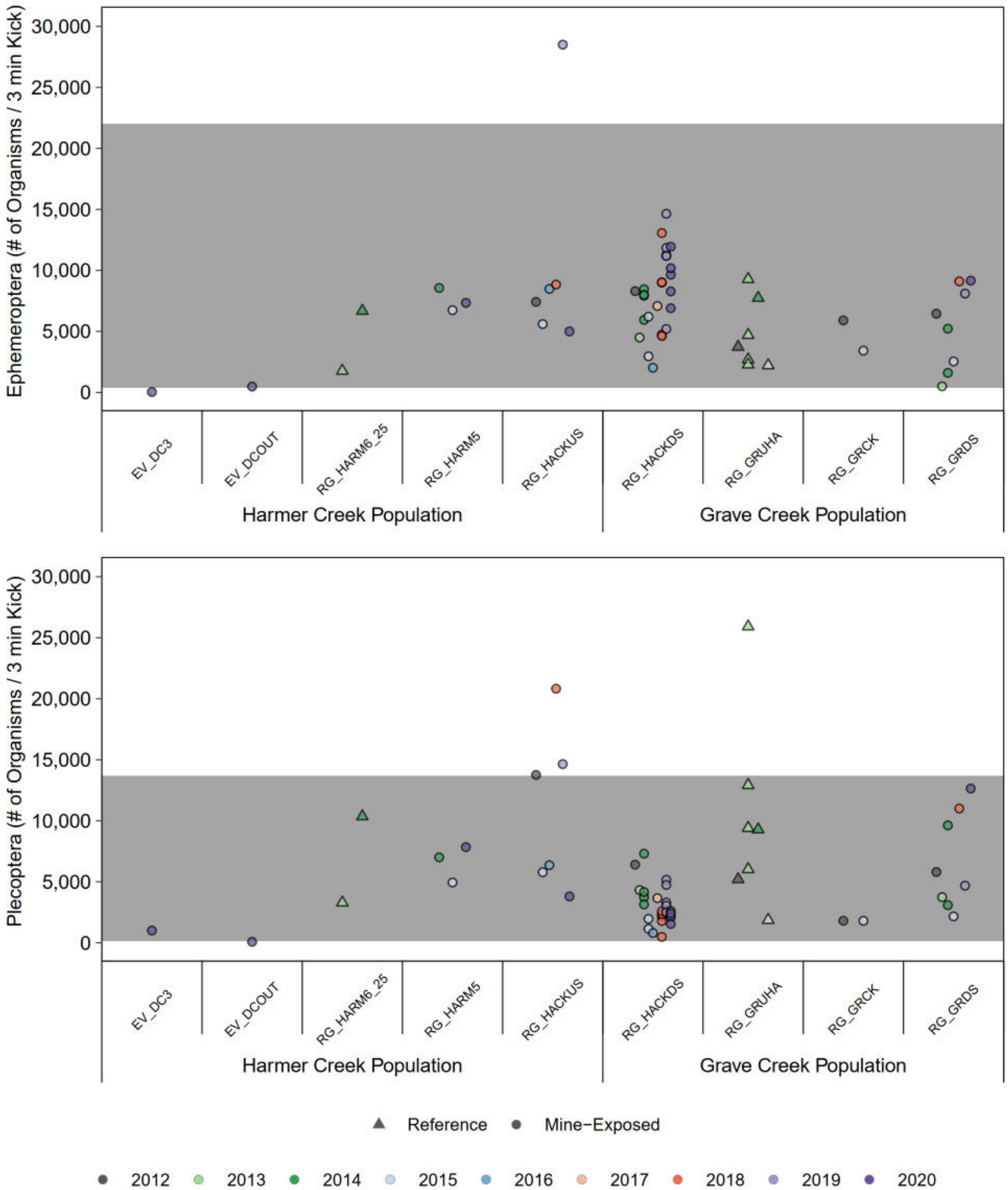

Figure 3.2: Benthic Invertebrate Abundance in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

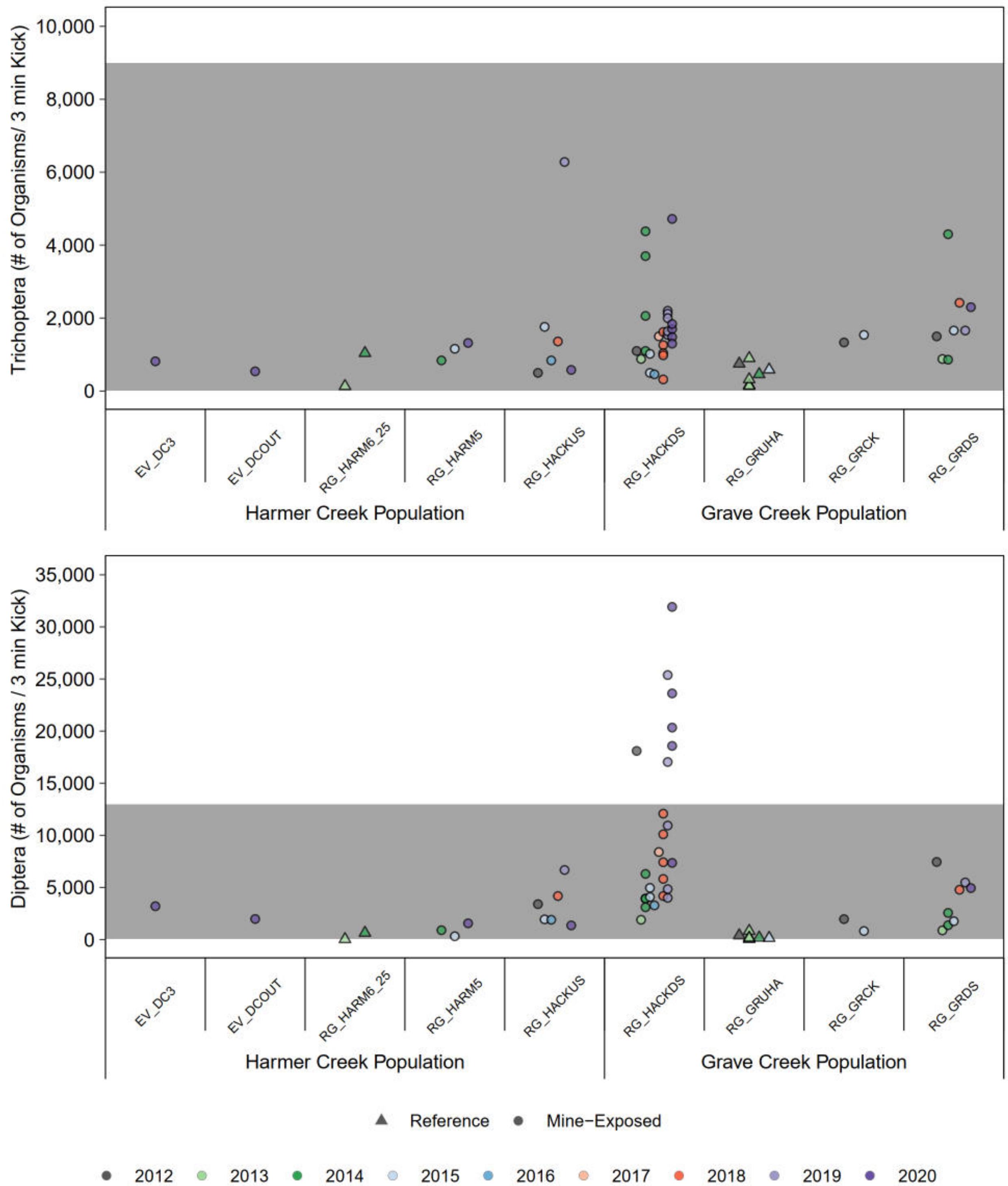

Figure 3.2: Benthic Invertebrate Abundance in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

As noted in Section 1.1.2, EPT and dipterans are important dietary organisms for Westslope Cutthroat Trout of all ages. Therefore, differences in benthic invertebrate community composition among sampling areas and over time are considered potentially indicative of differences in food quality between the Harmer Creek and Grave Creek population areas. Similar to total abundance, EPT abundance was within or above the regional reference area normal range (Figure 3.2; Appendix Table A.5). When considered separately, abundances of Ephemeroptera, Plecoptera, and Trichoptera were also generally within or above their respective regional reference area normal ranges. Exceptions occurring during the period of interest for reduced recruitment included ephemeropteran abundance at EV_DC3 and plecopteran abundance at EV_DCOUT, both of which were below their respective reference area normal ranges in 2020 (Figure 3.2; Appendix Table A.5). Again, both of these sampling locations are within Dry Creek and the Harmer Creek population area. Samples were not collected prior to 2020 on Dry Creek; however, extensive calcite deposits were present in Dry Creek in the years leading up to and during the period of interest. Although there is some associated uncertainty, it is not unreasonable to assume the results observed in Dry Creek in 2020 were not unique to the period of reduced recruitment. Dipteran abundance was within or above the regional reference area normal range for all monitoring areas except the reference area HARM6_25 in the Harmer Creek population area in 2013 (n = 1; Figure 3.2; Appendix Table A.5).

In addition to assessment of absolute organism abundances (i.e., food quantity), relative taxon proportions (%) were evaluated as an indicator of potential differences in food and overall environmental quality[30] among areas or over time. Proportions of EPT taxa were within or above the regional reference area normal range for most biological monitoring areas and years, regardless of whether the samples were collected from the Harmer Creek or Grave Creek population areas (Appendix Figure A.4). Exceptions included EV_DC3 and EV_DCOUT, both of which are located on Dry Creek (Harmer Creek population area) and were sampled in 2020 only (n = 1 replicate per area). The next downstream monitoring area on Harmer Creek (RG_HARM5) had %EPT near top of the reference area normal range in 2020, suggesting potential localized benthic invertebrate community effects within Dry Creek. The Dry Creek community had relatively fewer Ephemeroptera (mayflies) and Plecoptera (stoneflies; at EV_DCOUT) and more Diptera (true flies) compared to reference area normal ranges (Appendix Figure A.4). The proportion of EPT was also low at RG_HACKDS on Harmer Creek downstream from the Harmer Creek Sedimentation Pond (Grave Creek population area) in some years (Appendix Figure A.4; Appendix Table A.5). This was related to proportions of Ephemeroptera, Plecoptera, and/or

[30] Ephemeroptera, Plecoptera, and Trichoptera are considered sensitive to anthropogenic stressors and changes in habitat in the stream environment; Diptera are considered tolerant of many environmental conditions.

Trichoptera that were at the low end of their respective reference area normal ranges and %Diptera at the high end of (or above) the reference area normal range at RG_HACKDS (Appendix Figure A.4). Proportions of Diptera were also within or above the regional reference area normal range at monitoring areas in the Harmer Creek and Grave Creek population areas, except at reference areas located in the upper reaches of Harmer Creek (i.e., HARM6_25 in 2013) and Grave Creek (i.e., RG_GRUHA in 2013 and 2014) (Figure 2.1 and Appendix Figure A.4).

Three biological monitoring areas in the Harmer Creek population area (i.e., RG_HARM6_25, RG_HARM5, and RG_HACKUS) had at least two years of data to support the evaluation of temporal changes in benthic invertebrate abundances (Figure 3.3; Table 3.3; Appendix Figures A.5 to A.9; Appendix Tables A.6 to A.10) and taxonomic proportions (Appendix Figures A.10 to A.14; Appendix Tables A.11 to A.15). Each of the four biological monitoring areas in the Grave Creek population area had more than two years of data. No significant decreases in total abundance and the abundances of EPT or individual taxonomic groups (including Ephemeroptera, Plecoptera, Trichoptera, and Diptera) were identified over time for the Harmer Creek population area. This indicates that the quantity of food available to the Harmer Creek Westslope Cutthroat Trout population during the years associated with reduced recruitment was no different than in previous years (Figure 3.3; Table 3.3; Appendix Figures A.5 to A.9; Appendix Tables A.6 to A.10). Similar to abundance, temporal trends in the proportions of major taxonomic groups in the samples suggest there were no major shifts in community composition over time within the Harmer Creek population area, except for slightly more Plecoptera in the 2012 and 2018 versus 2019 and 2020 samples from RG_HACKUS (Appendix Figures A.10 to A.14; Appendix Tables A.11 to A.15).

Although endpoints related to aquatic invertebrate quality and quantity were not measured directly in stream drift, benthic invertebrate data indicate that community characteristics remained stable since 2012 and did not differ substantially between the Harmer Creek and Grave Creek population areas. The abundances and composition of key dietary organisms for the Harmer Creek Westslope Cutthroat Trout population were similar or greater in years associated with reduced recruitment when compared to prior years. Overall, the benthic invertebrate monitoring results provide evidence contrary to the hypothesis that the quantity and/or quality of aquatic invertebrates decreased sufficiently to cause or contribute to the reduced recruitment observed for the 2017 to 2019 spawning year cohorts in the Harmer Creek Westslope Cutthroat Trout population. Data gaps and uncertainties associated with this assessment are discussed in Section 3.4.2.

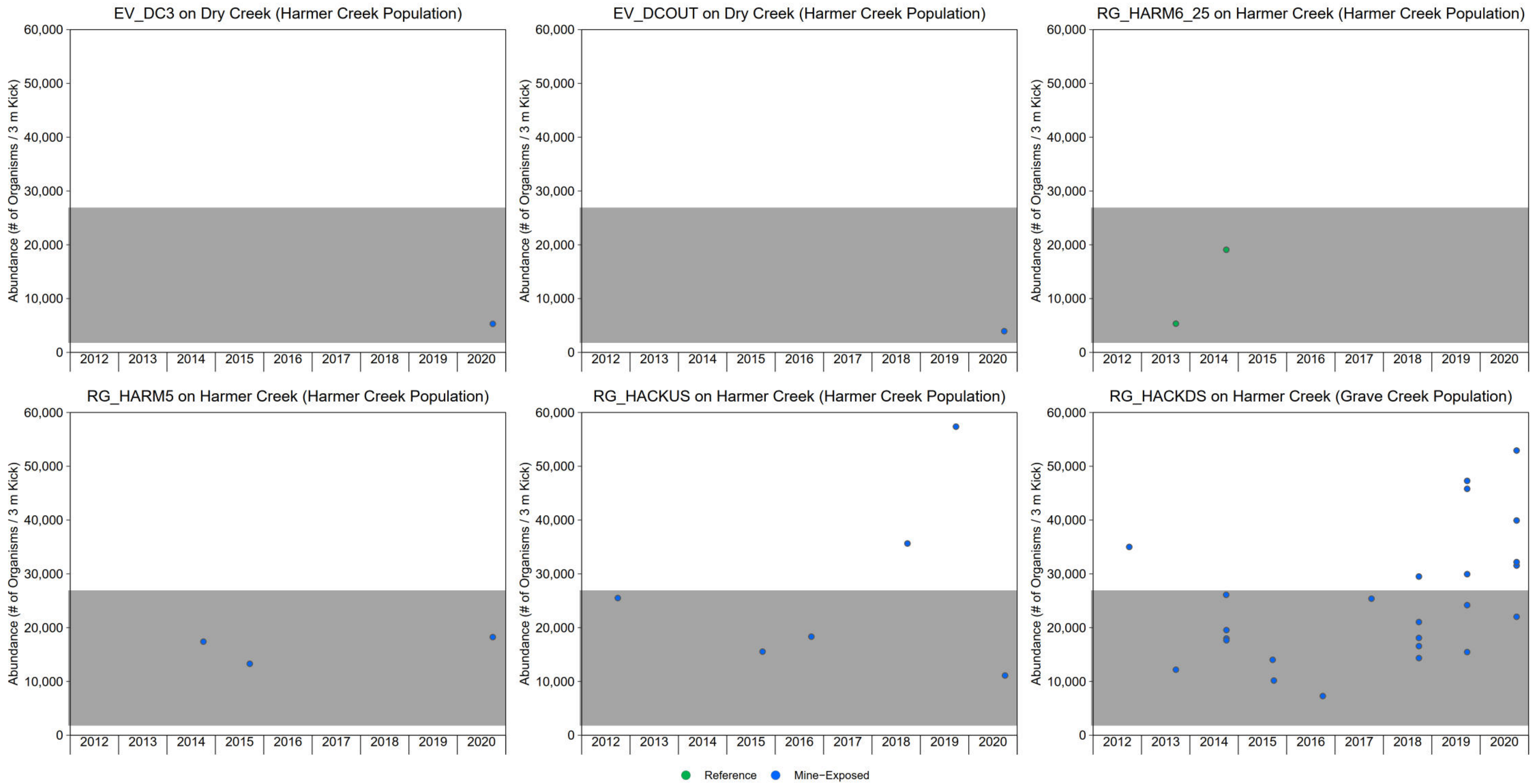

Figure 3.3: Benthic Invertebrate Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

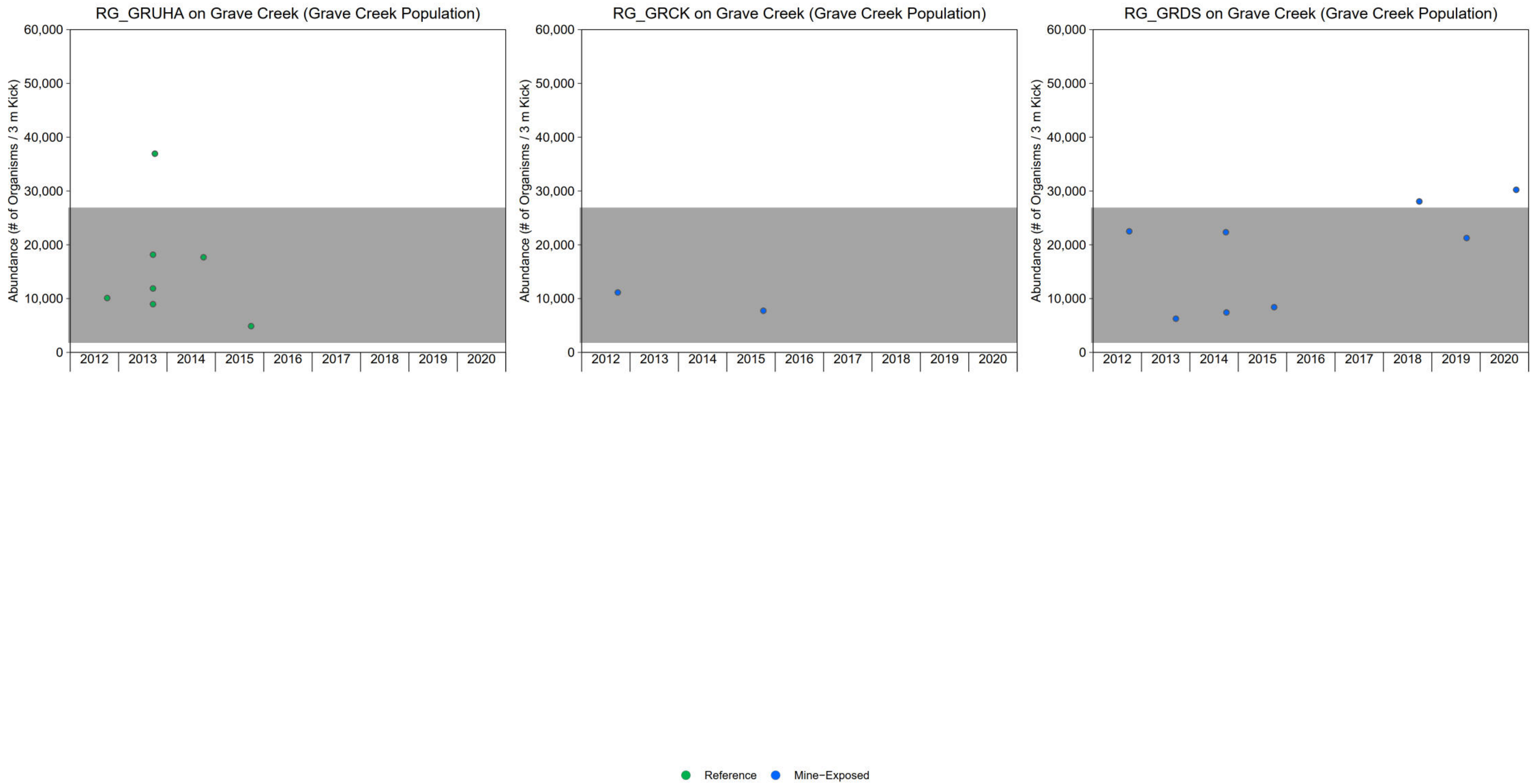

Figure 3.3: Benthic Invertebrate Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

Table 3.3: Temporal Changes in Total Benthic Invertebrate Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.466	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	1.000	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.182	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.250	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.058	base year	-2.5	-1.3	-2.6	-3.8	-0.77	-1.4	-0.37	-0.051	AB	AB	AB	AB	B	AB	AB	AB	A
		RG_GRCK	0.999	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.222	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

P-value <0.1.
>2 SD increase.
>3 SD increase.
>4 SD increase.
>5 SD increase.
>2 SD decrease.
>3 SD decrease.
>4 SD decrease.
>5 SD decrease.
bold Significant increase or decrease from base year.
Significantly greater than historical years.
Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[\text{Mean}_{\text{given year}} - \text{Mean}_{\text{base year}}]/\text{SD}_{\text{base year}}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

3.3 Terrestrial Invertebrates

Inputs of terrestrial invertebrates to streams are strongly linked to the amount and type of riparian vegetation (Albertson et al. 2018; Romero et al. 2005; Studinski et al. 2017; Wipfli 1997) and surrounding land use (Edwards and Huryn 1996; Erös et al. 2012).

The total areas of riparian habitat in both the Harmer Creek and Grave Creek population areas were unchanged between 2016 and 2020 (Table 3.4). The areas of land disturbed by mining and other causes (e.g., fire, forestry) within each population area were also unchanged over the same period. Given that there was no change in the amount of disturbed habitat, or new disturbances, in the Harmer Creek and Grave Creek population areas, it is unlikely that the types of riparian vegetation present would have changed between 2016 and 2020. Therefore, the evidence indicates that the decline in Westslope Cutthroat trout recruitment in Harmer Creek was not attributed to reduced dietary availability of terrestrial invertebrates.

3.4 Data Gaps and Uncertainties

3.4.1 Westslope Cutthroat Trout

Sample sizes for Westslope Cutthroat Trout length and body condition were very small for some age/size classes, areas, and/or years. Few length data were available for fry captured prior to and during the period of reduced recruitment (Thorley et al. 2022). Additionally, the sample size for juvenile Westslope Cutthroat Trout representing the 2018 spawning year cohort was sufficiently small (i.e., n = 3) that this year of data could not be included in statistical contrasts among areas or years. Only five juvenile Westslope Cutthroat Trout were captured from the Harmer Creek population area in 2020. Additionally, there were fewer than 10 juvenile Westslope Cutthroat Trout captured from the Grave Creek population area in 2008 and in both the Harmer Creek and Grave Creek population areas in 2013. There were also fewer than 10 adult Westslope Cutthroat Trout captured from both the Harmer Creek and Grave Creek population areas in 1996, 2008, and 2013. Therefore, condition factors and lengths of fry, in particular, reported for those years may not be representative of the respective populations as a whole. Because the patterns of recruitment in the Harmer Creek and Grave Creek populations differed during 2017 to 2019, spatial comparisons (between systems) are most informative compared to temporal comparisons (among years within each system). Although body length and condition data were lacking for juveniles spawned in 2018 (and to a lesser extent, 2019) in Harmer Creek, there were adequate data to compare adult fish condition between the Harmer Creek and Grave Creek populations in the years 2017 through 2020. As the invertebrate prey species of juveniles and adults broadly overlap, it is likely that a substantive change in food availability for juveniles would also be reflected in the body condition of adults. Furthermore, evaluations of aquatic and terrestrial food

Table 3.4: Changes in Riparian and Disturbance Areas Between 2016 and 2020

Location and Terrestrial Characteristics		Area (km^2)			% Change
		2016	2020	Difference	
Harmer Creek Population Area	Riparian habitat	1.0	1.0	0	0
	Total watershed area	37	37	0	0
	Total mine-disturbance footprint	3.5	3.5	0	0
	Footprint of other disturbances (e.g., fire, forestry cutblocks)	0.52	0.52	0	0
	Undisturbed	33	33	0	0
Grave Creek Population Area	Riparian habitat	1.1	1.1	0	0
	Total watershed area	30	30	0	0
	Total mine-disturbance footprint	0.04	0.04	0	0
	Footprint of other disturbances (e.g., fire, forestry cutblocks)	2.4	2.4	0	0
	Undisturbed	30	30	0	0

Notes: km^2 = square kilometres; % = percent; < = less than.

supply also indicated no change in food availability in Harmer Creek compared to Grave Creek during the period of reduced recruitment.

Measurements of fish length and weight were made in late summer or early fall, whereas mortalities related to energy deficits often occur in winter. The largest seasonal decline in body energy stores typically occurs in fall or early winter and is associated with physiological adjustment to lower water temperatures and freezing, as well as decreased photoperiod (Cunjak and Power 1987; Cunjak et al. 1987; Handy 1997; Huusko et al. 2007). Although colder water temperatures reduce gut evacuation rates and metabolic demand (Berg and Bremset 1998; Brown et al. 2011), and salmonids continue to feed in winter (Brown et al. 2011; Cunjak and Power 1987; Cunjak et al. 1987), appetite, prey capture efficiency, and digestion efficiency may decline (Brown et al. 2011; Cunjak and Power 1987; Cunjak et al. 1987). Therefore, energy deficits can still occur and contribute to winter mortality (Biro et al. 2004; Brown et al. 2011; Handy 1997; Huusko et al. 2007). Native species that are adapted to winter survival increase body size and store lipids in summer, and these factors contribute to greater overwinter survivorship, particularly for juveniles (Biro et al. 2004; Quinn and Peterson 1996). Therefore, late summer body condition and, to a greater extent, body length, of trout are indicators of overwinter survival.

Body condition is not always a reliable indicator of lipid reserves. Although declines in body condition based on length and weight measurements have been used to indicate starvation processes among salmonids during winter, body condition is not always a reliable indicator of energy reserves and survival (Handy 1997; Robinson 2010; Simpkins et al. 2003). This is because body condition does not only reflect lipid reserves but is also related to the amount of moisture stored in tissues (Handy 1997; Robinson 2010). However, the evaluation presented in this report includes lines of evidence in addition to the evaluation of body condition, all of which supported a conclusion that it is unlikely that a reduction in food availability can account for the reduced recruitment in the Harmer Creek population.

There were no data were available to evaluate condition of Westslope Cutthroat Trout mortalities. Because there are no length or weight data for the mortalities from the 2017 to 2019 cohorts, it is uncertain whether these individuals would have shown a clear signal indicating reduced condition, even when the data for survivors did not. There is some evidence in the literature for juvenile trout that indicates mortalities can exhibit poorer condition relative to surviving individuals (Keeley 2001).

3.4.2 Westslope Cutthroat Trout Diet

The composition of aquatic invertebrate species in drift and Westslope Cutthroat Trout diet were not measured directly. Positive correlations have been reported between benthic and drift densities for dominant drifting orders (Ephemeroptera, Diptera, and Trichoptera; Shearer et al. 2003). However, the relative abundance of taxa in drift may not directly correlate to that of the benthic community (Naman et al. 2016; Shearer et al. 2003). Also, trout diet does not always reflect the proportional abundance of invertebrates in drift, indicating prey selectivity (Fochetti et al. 2003). The specific occurrence of aquatic invertebrate taxa in drift at any given time is determined by complex, interdependent factors including life cycle, illumination, stream discharge, population density, water chemistry (e.g., dissolved oxygen, pH), and behavioural characteristics (Barbero et al. 2013; Lehmkuhl and Anderson 1972; Naman et al. 2016; Pearson and Franklin 1968). Therefore, although the benthic invertebrate community data are not indicative of food limitations, there are a number of influencing factors and related uncertainties associated with each step between benthic invertebrates being present in the substrates and Westslope Cutthroat Trout being able to store energy from food.

Salmonids can switch dietary reliance from terrestrial invertebrates to aquatic (Baxter et al. 2005; Nakano et al. 1999; Studinski et al. 2017), or the reverse (Kraus et al. 2016), and from drift to benthic organisms (Dunham et al. 2000; Nakano et al. 1999; Zhang and Richardson 2011) in response to availability and quality. Older juveniles and adults will also move in search of food if local resources are limited (COSEWIC 2006; Schmetterling 2011; Wilzbach 1985). The literature also indicates that stream invertebrate drift is usually lowest in winter (Romaniszyn et al. 2007; Syrjänen et al. 2011) and that salmonids often shift to benthic foraging in winter (Anderson et al. 2016; Cunjak and Power 1987). Therefore, benthic invertebrate abundances provide a reasonable basis for assessing changes in food availability over the period of reduced recruitment in the Harmer Creek Westslope Cutthroat Trout population. However, it is recognized that there are uncertainties around the extent to which juvenile fish, in particular, in the Harmer Creek population area switch dietary reliance or move around in search of food, as well as the energetic costs associated with movements in search of food.

Benthic invertebrate sample sizes were small or lacking in some areas and/or years. For example, there was only one year of data, and a single sample per area, for the biological monitoring locations on Dry Creek, which flows to Harmer Creek and is used by Westslope Cutthroat Trout. However, data were adequate to support general comparisons between the Harmer Creek and Grave Creek population areas relative to reference area normal ranges, and for statistical comparisons over time at biological monitoring areas on Harmer Creek. Considering the limitations of the data set, Teck Coal completed benthic invertebrate community sampling at EV_DC3, EV_DCOUT, and other biological monitoring areas on Harmer and Grave creeks in 2021 and 2022, concurrent with annual sampling completed as part of the RAEMP.

Potential changes in terrestrial drift abundance were inferred from landscape indicators rather than direct measurement. However, the diet of Westslope Cutthroat Trout in the Elk River watershed is dominated by aquatic invertebrates and, as noted above, trout can shift foraging behaviour from terrestrial to either drifting or benthic aquatic invertebrates and will also move in search of food. Wilson et al. (2014) concluded that benthic invertebrate biomass in streams, not the magnitude of terrestrial invertebrate inputs, determined the proportional use of terrestrial and aquatic invertebrates by trout during summer months. Therefore, a decline in terrestrial invertebrates may have little effect on trout in a system with good benthic invertebrate abundance, such as in Harmer and Grave creeks. Also, the drift structure at a given place in a stream depends not only on local production but also on areas further upstream (Barbero et al. 2013; Wipfli and Baxter 2010; Wipfli and Gregovich 2002). For example, terrestrial invertebrates falling or washing into streams in a headwater may be consumed by fish farther downstream (previous references). So, the specific locations of riparian or terrestrial disturbances are not as important for assessing potential effects on fish as the overall amount of undisturbed riparian and upland habitat, which remained constant over the period of reduced recruitment in the Harmer Creek Westslope Cutthroat Trout population.

4 CONCLUSIONS AND STRENGTH OF EVIDENCE

The results of the data evaluation did not align with expected outcomes for a reduction in food availability to cause or contribute to reduced recruitment for the Harmer Creek Westslope Cutthroat Trout population. Specifically:

- The condition of adult spawners in Harmer Creek in the years during and leading up to the period of reduced recruitment was not reduced relative to previous years, or relative to the condition of adult spawners in the Grave Creek population, or other Upper Kootenay Westslope Cutthroat Trout populations;
- Juvenile condition was not reduced in 2017, 2018, or 2020 compared to previous years; however, condition of juveniles was slightly (≤10%) lower in 2018 relative to 2017 and 2020;
- There were insufficient data for 2019 to evaluate condition in juvenile Harmer Creek Westslope Cutthroat Trout and no data were available to evaluate condition of mortalities in any given year;
- Analyses completed by other SMEs indicated ATU and dietary selenium may have contributed to reduced overwintering survival of fry by reducing the amount of time available to grow/store energy prior to winter and directly affecting the ability to increase in length following emergence, respectively;
- During the years of reduced recruitment, total benthic invertebrate abundances, as well abundances of taxa that are important dietary items, measured in samples from Harmer Creek, upstream of the Harmer Creek Sedimentation Pond, were within or above regional reference area normal ranges and comparable to previous years and to the Grave Creek population area; and
- Areas of riparian habitat and overall watershed disturbance have not changed over time in Harmer Creek, suggesting that terrestrial invertebrate contributions to drift were not likely reduced during the period of reduced recruitment.

However, there are uncertainties related to the following:

- Small sample sizes for juvenile Westslope Cutthroat Trout captured from the Harmer Creek population area in 2019 prevented statistical comparisons of weight at-length for that year;
- The reliability of late summer or early fall fish condition as an indicator of lipid (energy) reserves when mortalities related to energy deficits often occur in winter;

- The absence of length and weight data for age-0 and age-1 mortalities; and
- The use of indirect assessment methods to evaluate composition of aquatic invertebrate species and contributions of terrestrial invertebrates to in-stream drift and Westslope Cutthroat Trout diet.

Overall, the role of food availability as a causal or contributing factor in the reduced recruitment reported for the Harmer Creek Westslope Cutthroat Trout population is judged to be negligible (i.e., not a meaningful contributor). This is because fish condition in the years during the period of recruitment was not reduced relative to previous years or other populations, despite some subtle interannual variation. Additionally, the abundance and variety of prey available to Westslope Cutthroat Trout in the Harmer Creek population area were similar to the Grave Creek population area and similar or greater than in reference areas undisturbed by mining. Benthic invertebrate abundances did not decline during the period of reduced recruitment. Therefore, the available data for characterizing food availability indicate food limitation were unlikely to have adversely impacted survival, growth, or reproduction of the Harmer Creek population. Data gaps and uncertainties were generally offset by other lines of corroborating evidence. However, given the uncertainties around using indirect measures of invertebrate contributions to drift, Westslope Cutthroat Trout foraging behaviour, and factors related to the assimilation of food energy and metabolic requirements, the level of confidence in the conclusions drawn in this report is considered fair to moderate.

It is possible that reducing some of the uncertainties identified in Section 3.4 could result in food availability being identified as a minor, perhaps localized contributor to the reduced recruitment observed in the Harmer Creek population area. For example, benthic invertebrate community data for Dry Creek were limited to 2020 and indicated abundances of dietarily important taxa were on the low end of regional reference area normal ranges.[31] It is therefore possible that benthic invertebrate abundances in Dry Creek in other years of interest (i.e., 2017 to 2019) were less than the lower boundary of the reference area normal ranges. However, it is very unlikely that benthic invertebrates would have been totally absent from Dry Creek because other areas of the Elk River watershed that have been heavily influenced by mining and other disturbances have some benthic invertebrates present (Minnow 2018a, 2020). Even in the unlikely absence of invertebrates in Dry Creek, fish would have been able to consume terrestrial invertebrates in drift and move to Harmer Creek, where benthic invertebrate abundances were higher over the period of record (including the period of reduced recruitment). Also, it is likely that benthic invertebrate

[31] Proportions of Ephemeroptera and Plecoptera (one monitoring location each) in Dry Creek in 2020 were also lower than regional reference area normal ranges. Proportions of other dietarily important taxa (Trichoptera and Diptera) were within or above reference area normal ranges.

communities were influenced by the extensive calcification observed in Dry Creek prior to the period of reduced recruitment (Berdusco 2008; Lotic 2015).

Ultimately, it is not expected that resolving the key uncertainties identified in Section 3.4 would change the conclusions of the assessment to the extent that food availability would be reclassified as explaining most, if not all, of the observed reduction in recruitment. This is because, as indicated in Section 3.4, other stressors would need to act on the steps between benthic invertebrates being produced in the substrates (or even terrestrial invertebrates falling in the water) and fish putting on or maintaining energy stores. Additionally, even a worst-case condition of benthic invertebrate absence (i.e., no benthic invertebrates produced) in Dry Creek would be unlikely to result in major changes to Westslope Cutthroat Trout recruitment. Dry Creek represents approximately 17% of the stream length that could contribute to benthic invertebrate production.[32] Because benthic invertebrate habitat quality in Dry Creek is poor relative to Harmer and Grave creeks (Golder 2017; Lotic 2015; Nupqu and Hemmera 2020), it is likely that the contribution to the food base from Dry Creek has been much lower than 17% both historically and during the recruitment decline.

Benthic invertebrate community sampling in lotic habitats within Dry, Harmer, and Grave creeks was completed in September and early October 2021 and September 2022, concurrent with the fall surveys for the RAEMP. The results of this sampling are expected to reduce uncertainties in the assessment by improving spatial coverage and the ability to assess changes over time. At the time of writing, these 2021 and 2022 data were not available for use in the Harmer Creek EoC. Data from sampling in 2021 and 2022 will be reported and interpreted by Teck Coal in upcoming RAEMP reporting cycles.

[32] This estimate assumes HRM-R3 through HRM-R6 on the Harmer Creek main stem and DC-R1 through DC-R4 on Dry Creek contribute to invertebrate drift and is considered conservative because it ignores contributions from other tributaries and assumes invertebrates originating from downstream of HRM-R3 are transported to the Grave Creek population area (see Table 3.1 in Harmer Creek Evaluation of Cause Team [2023] for reach lengths).

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APPENDIX A
SUPPORTING INFORMATION

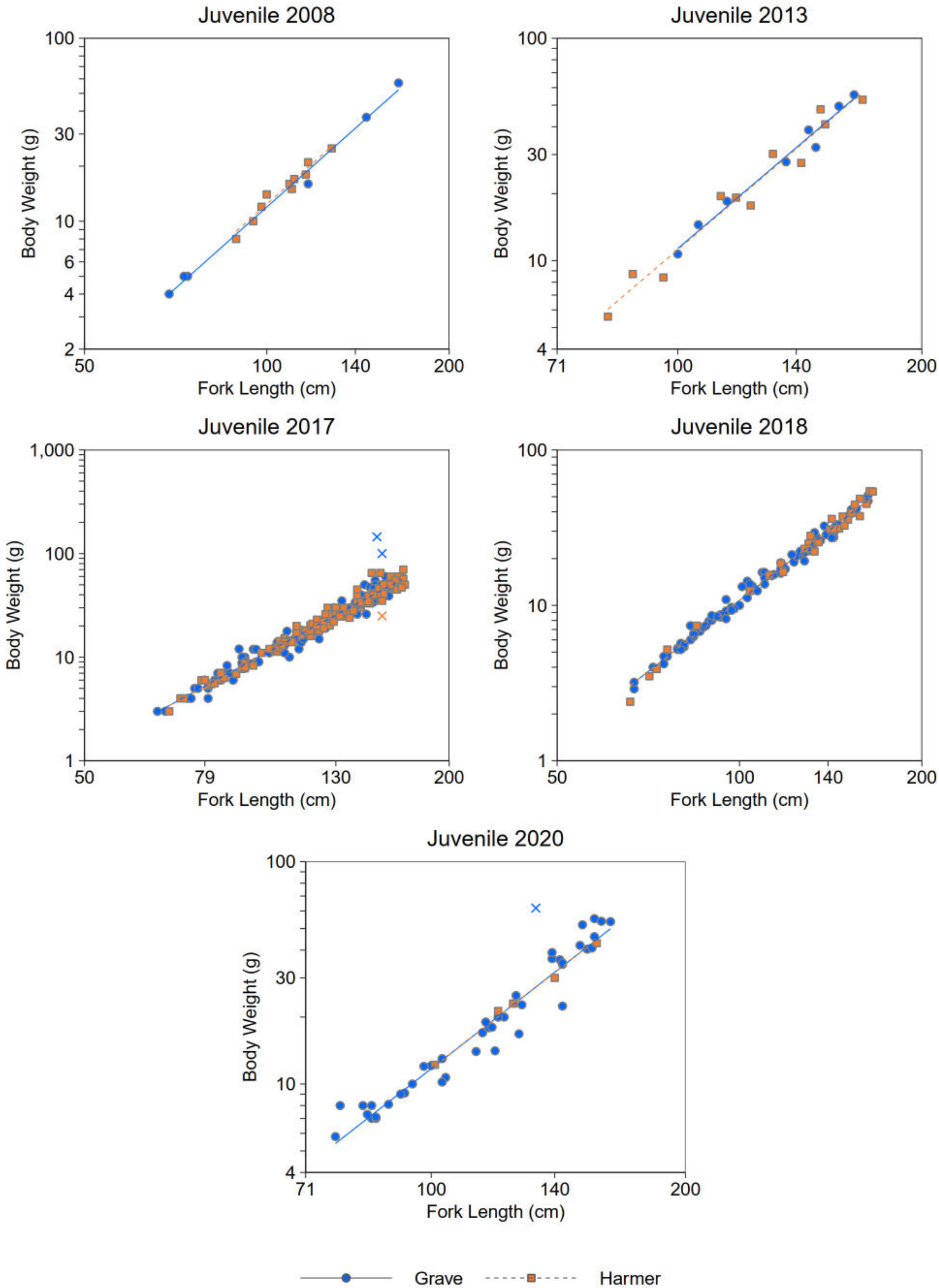

Figure A.1: Condition of Juvenile Westslope Cutthroat Trout from the Harmer Creek and Grave Creek Populations, 2008 to 2020

Notes: Outliers marked with an X. Data for Harmer Creek juveniles captured in 2019 were not plotted/included in the Analysis of Covariance (ANCOVA) due to the small sample size (n = 3).

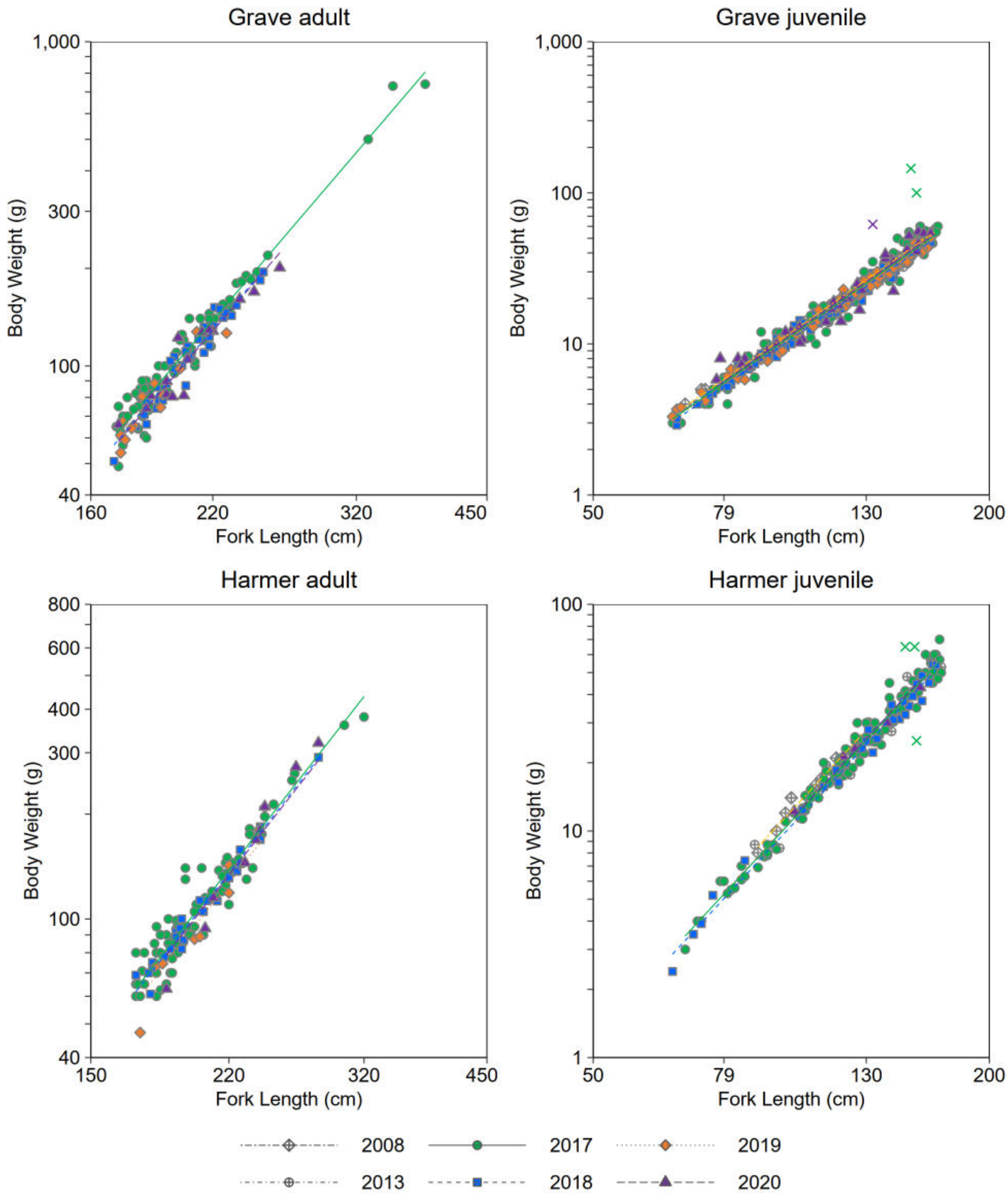

Figure A.2: Condition of Adult and Juvenile Westslope Cutthroat Trout from Harmer Creek and Grave Creek Populations, 1996 to 2020

Notes: Outliers marked with an X. Years that had sample size less than or equal 4 were excluded.

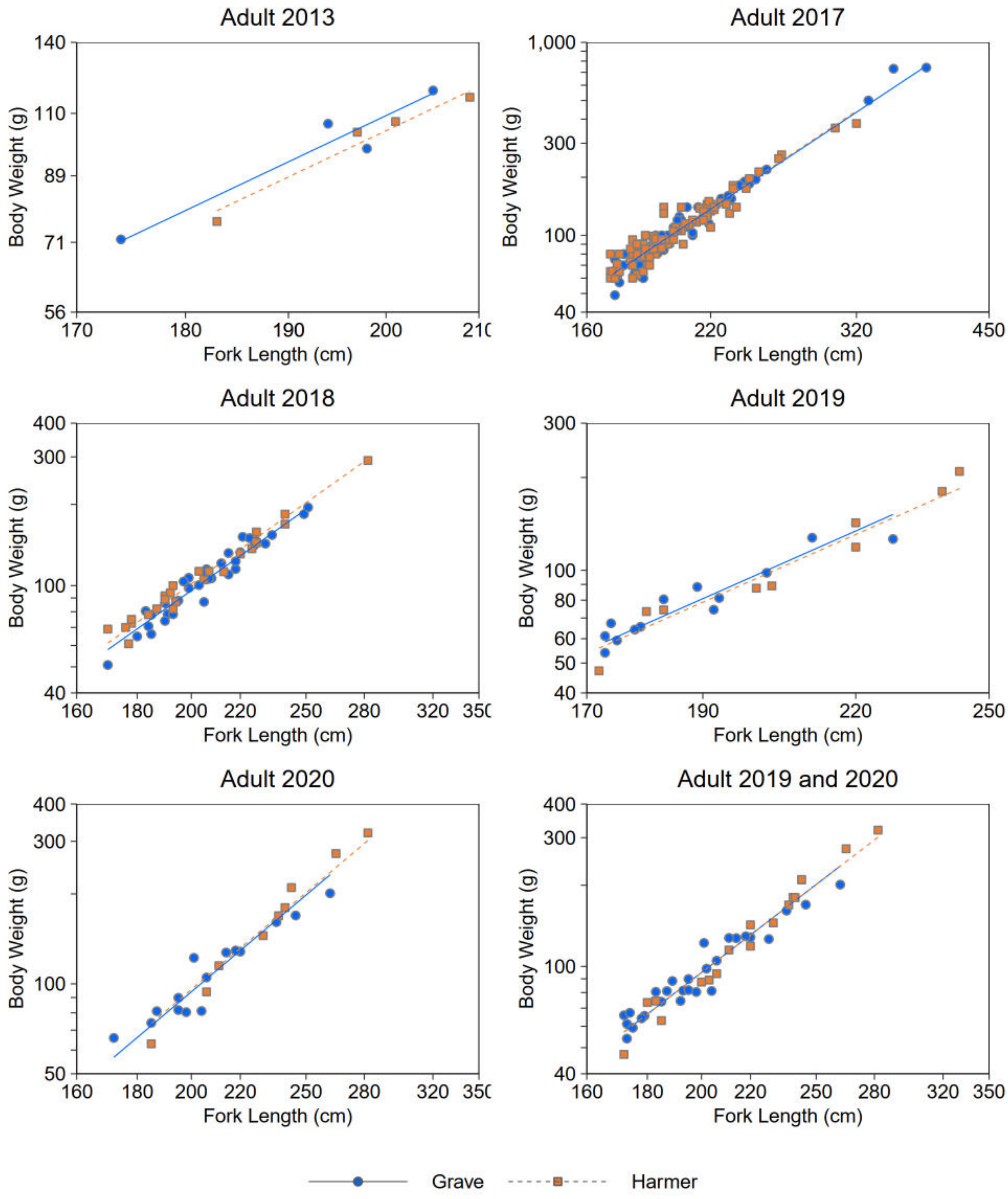

Figure A.3: Condition of Adult Westslope Cutthroat Trout from the Harmer Creek and Grave Creek Populations, 2013 to 2020

Notes: Outliers marked with an X.

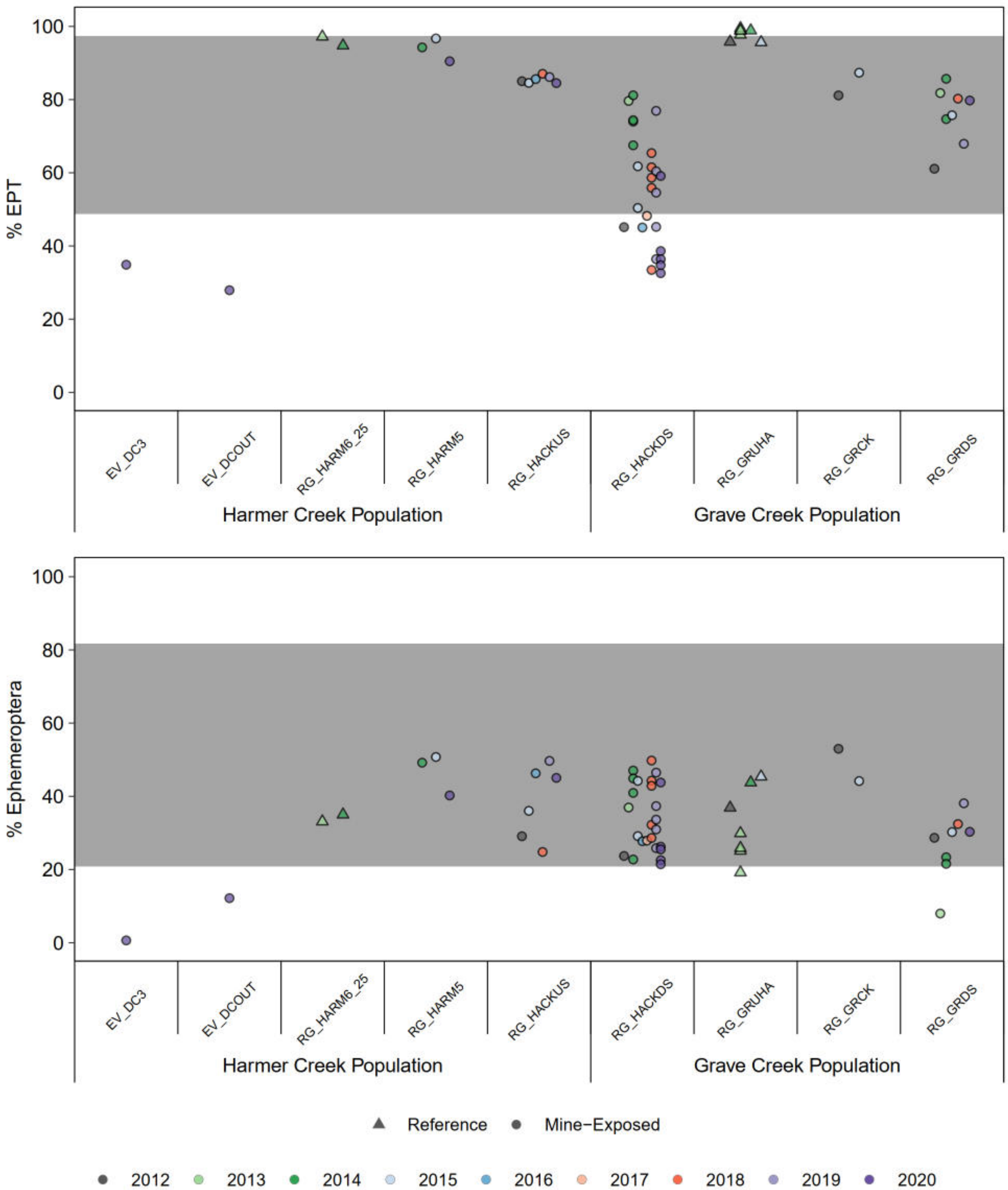

Figure A.4: Benthic Invertebrate Community Composition in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

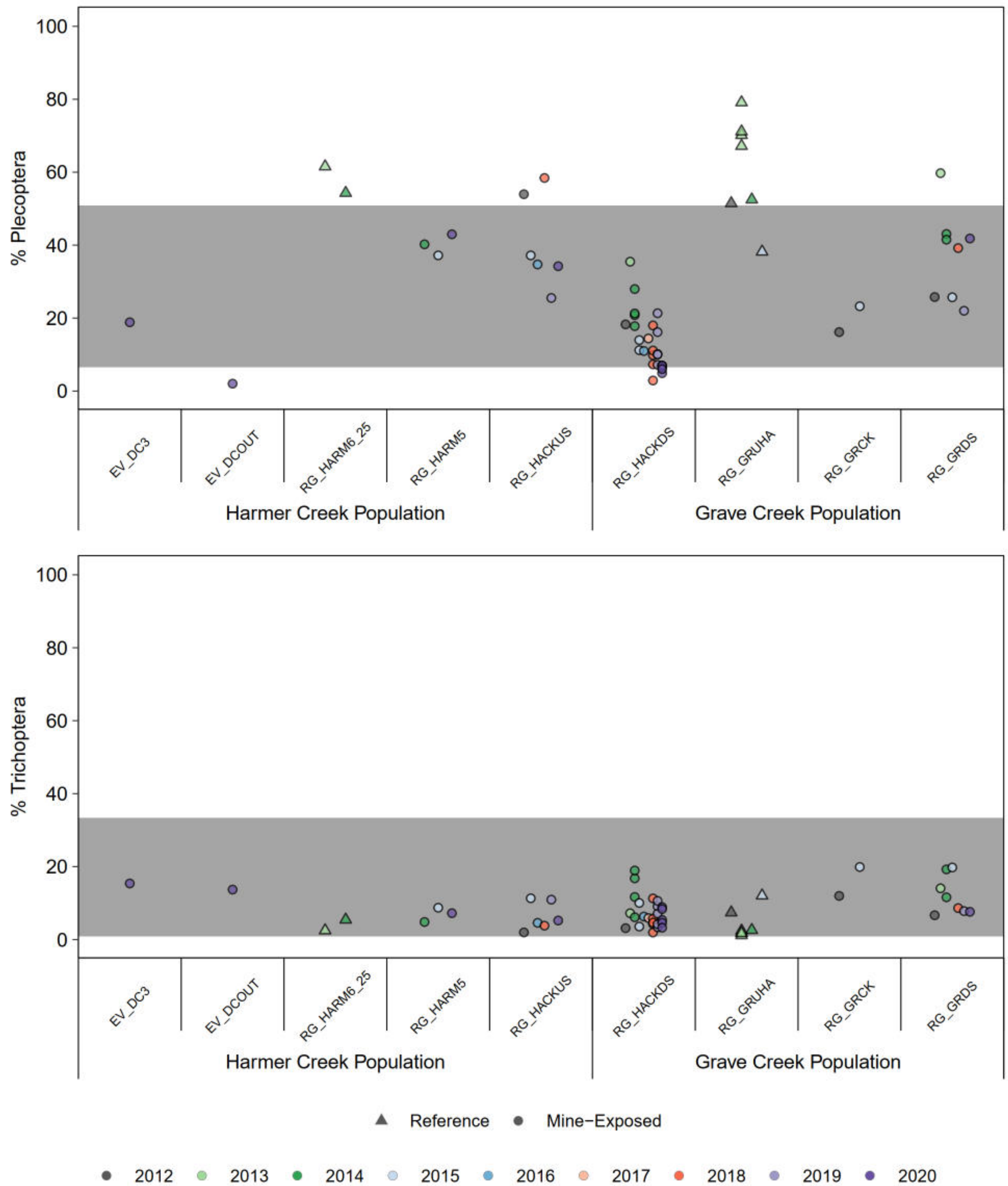

Figure A.4: Benthic Invertebrate Community Composition in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

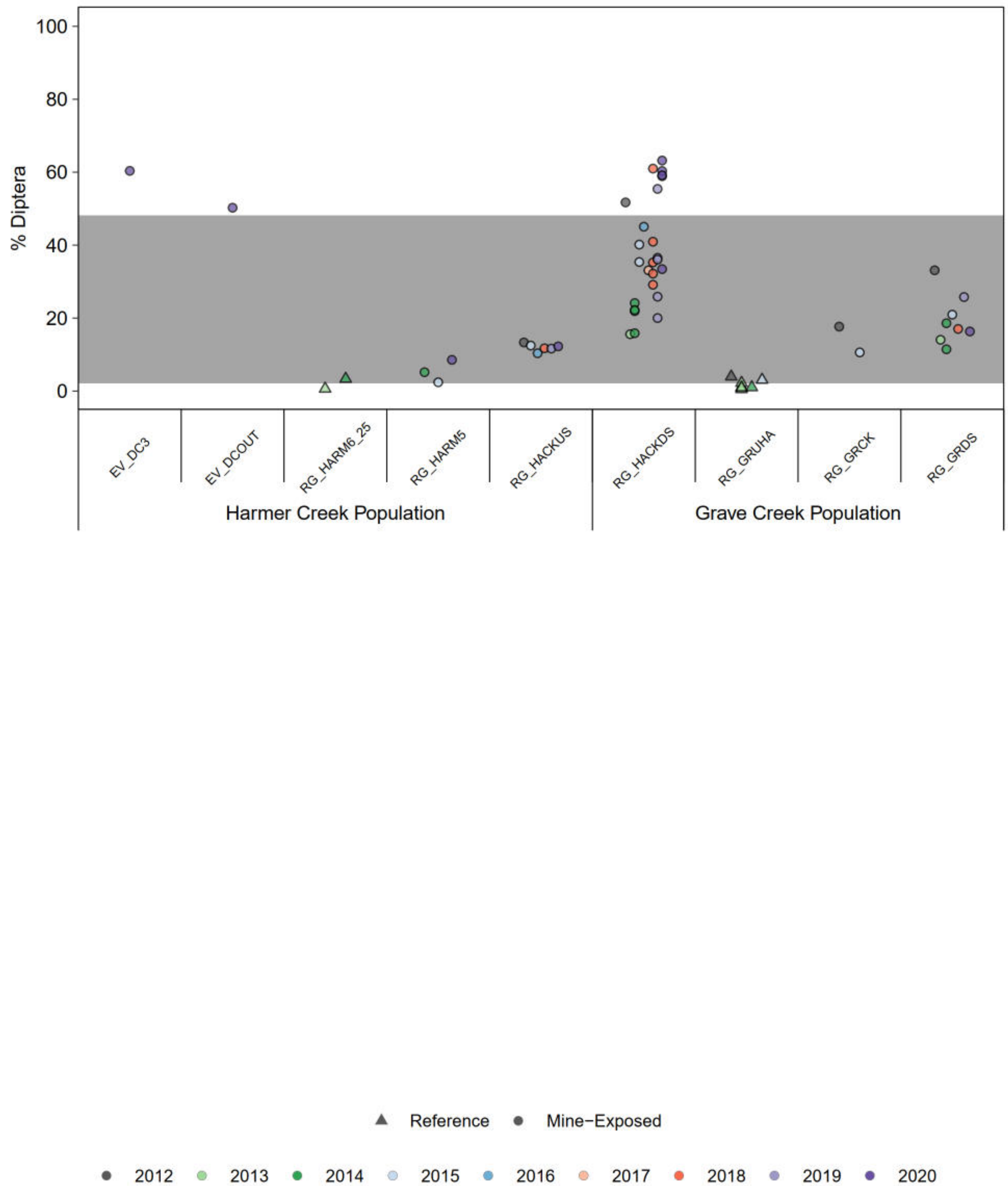

Figure A.4: Benthic Invertebrate Community Composition in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

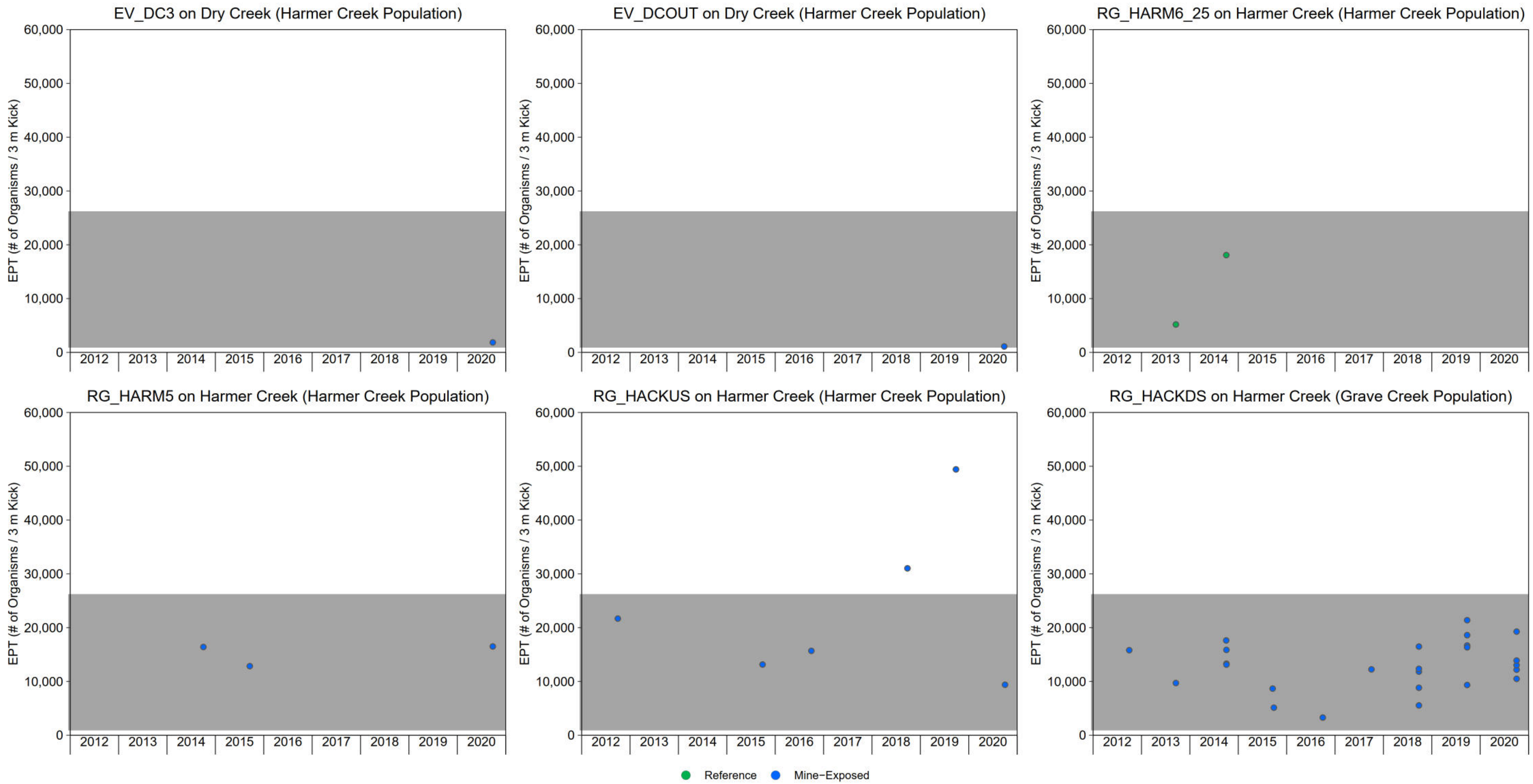

Figure A.5: Combined Abundance of Ephemeroptera, Plecoptera, and Trichoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

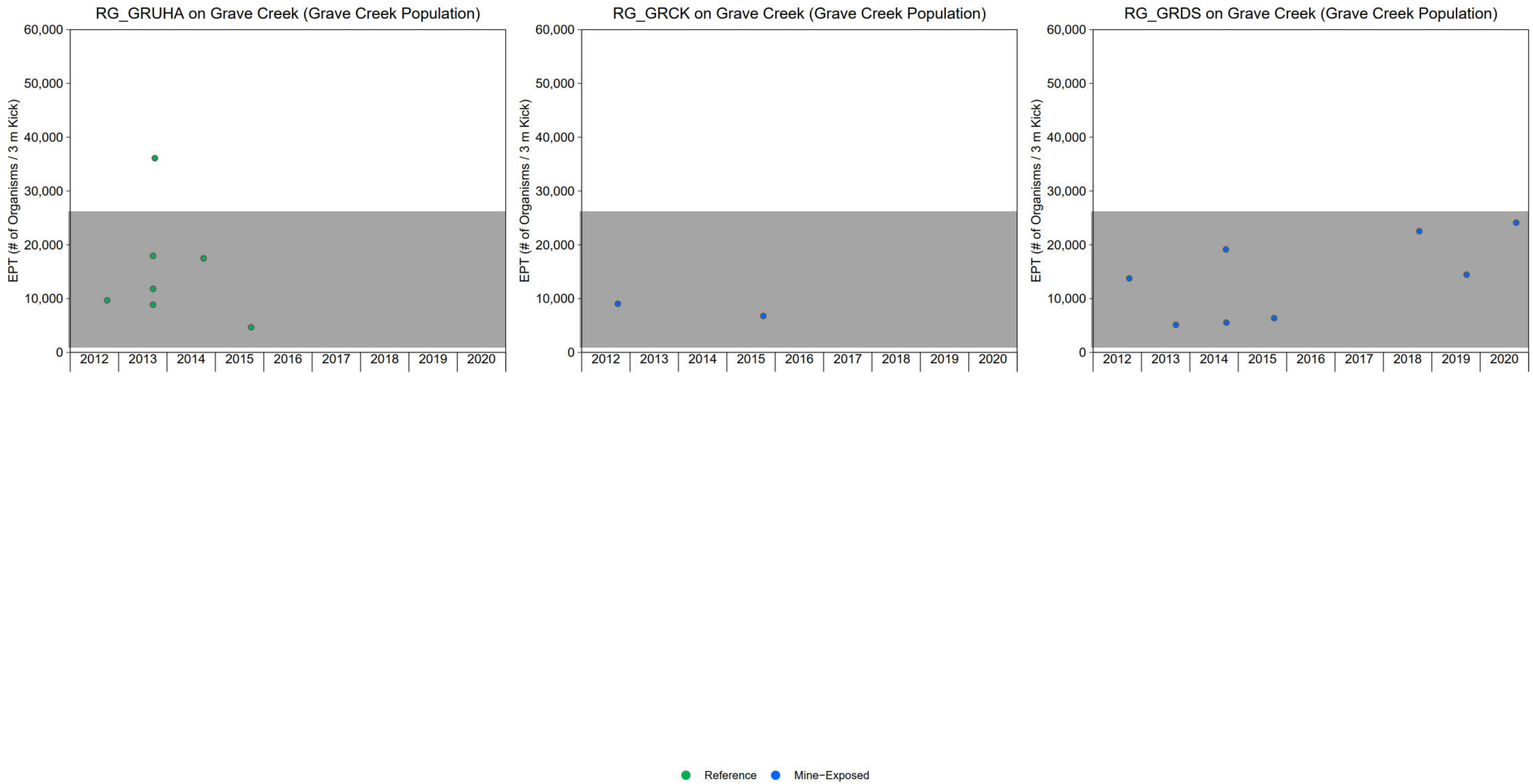

Figure A.5: **Combined Abundance of Ephemeroptera, Plecoptera, and Trichoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020**

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

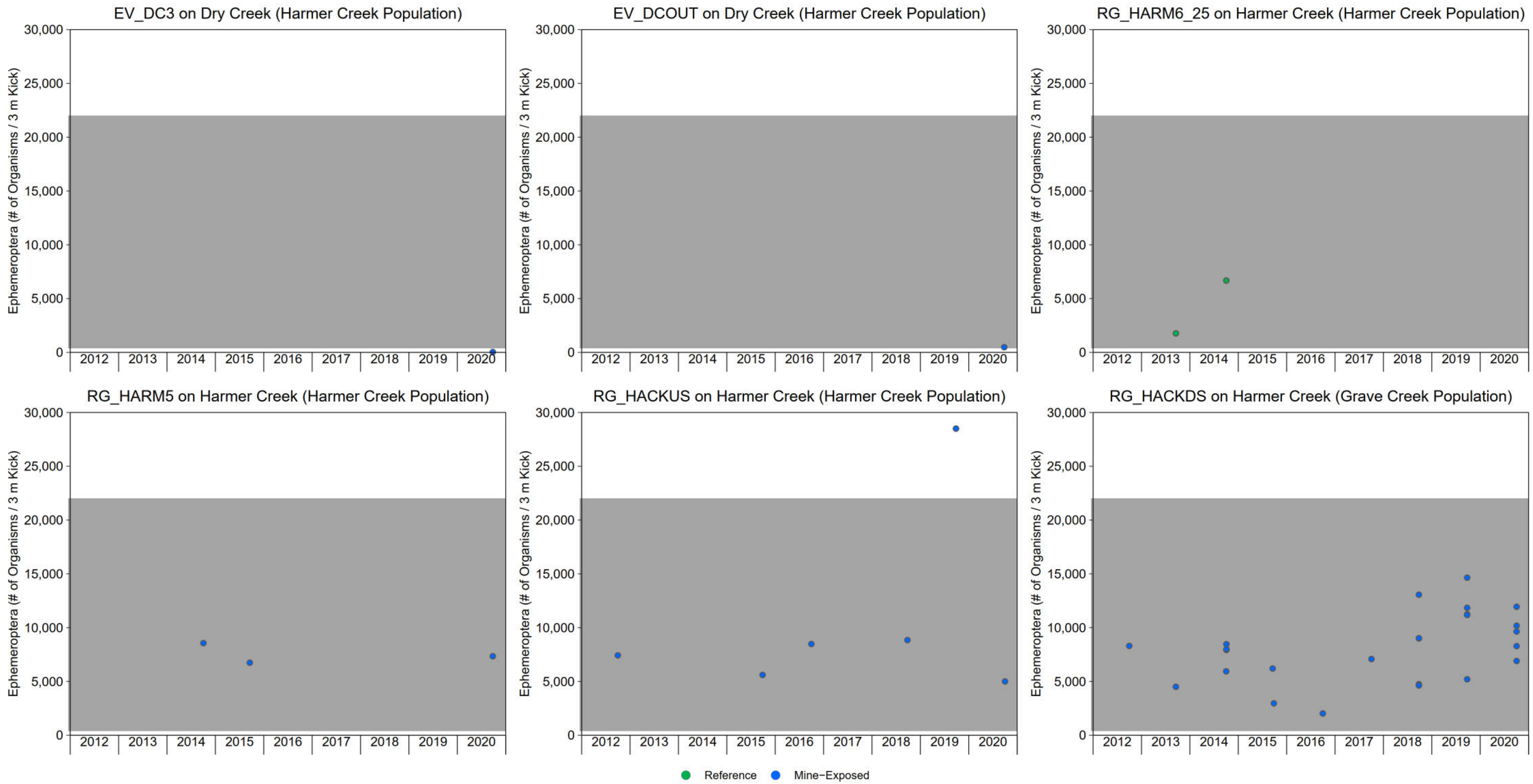

Figure A.6: Ephemeropteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

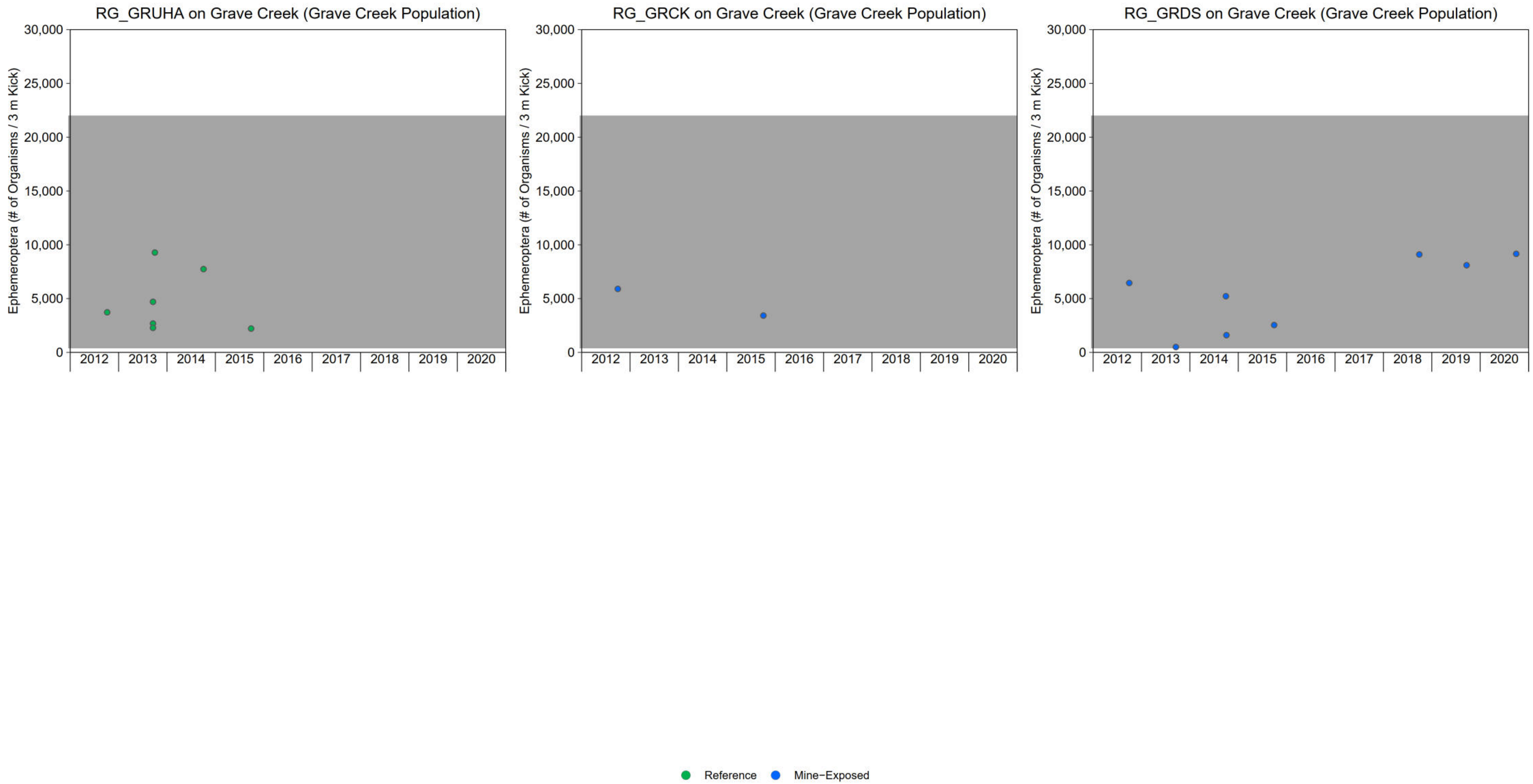

Figure A.6: Ephemeropteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

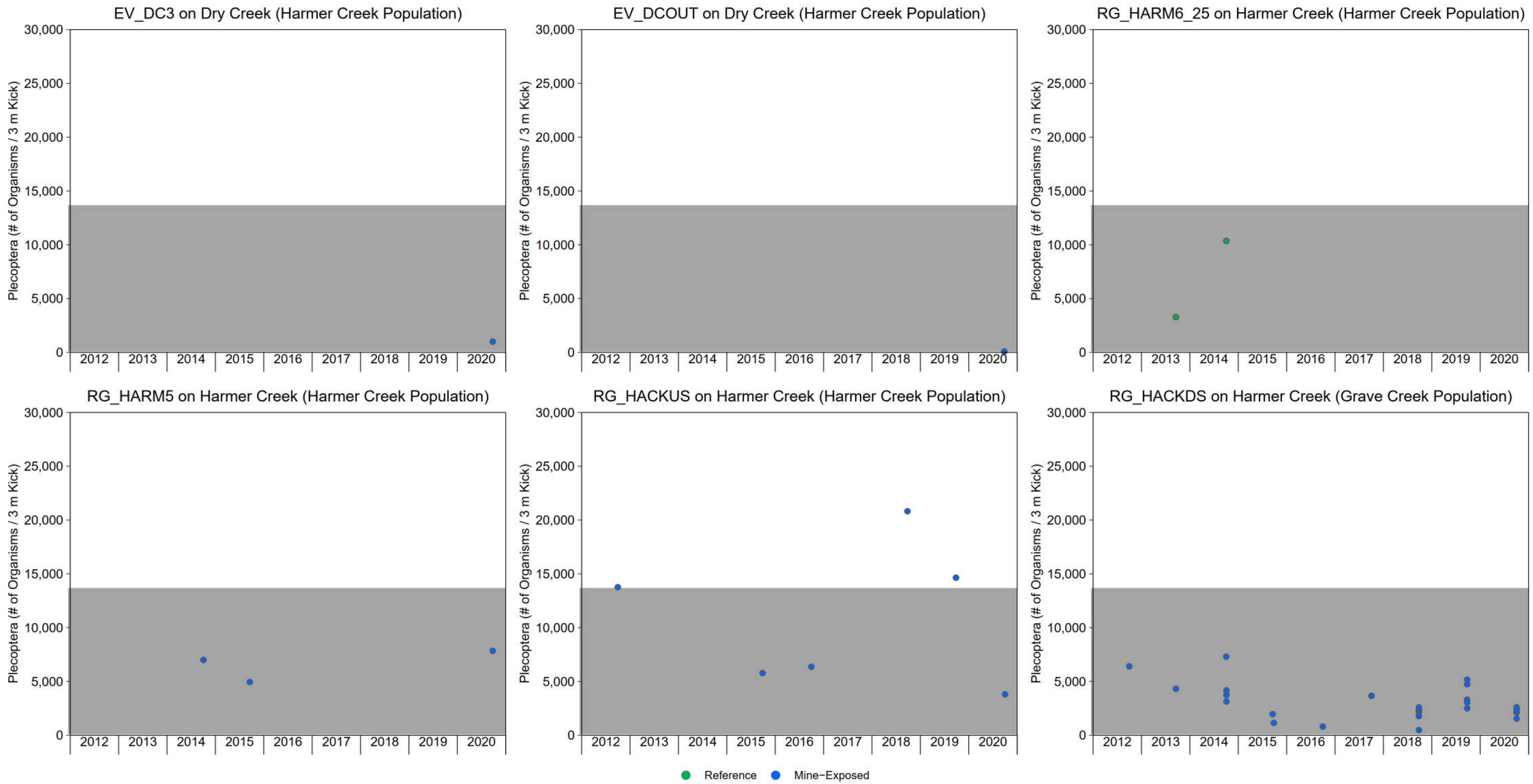

Figure A.7: Plecopteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

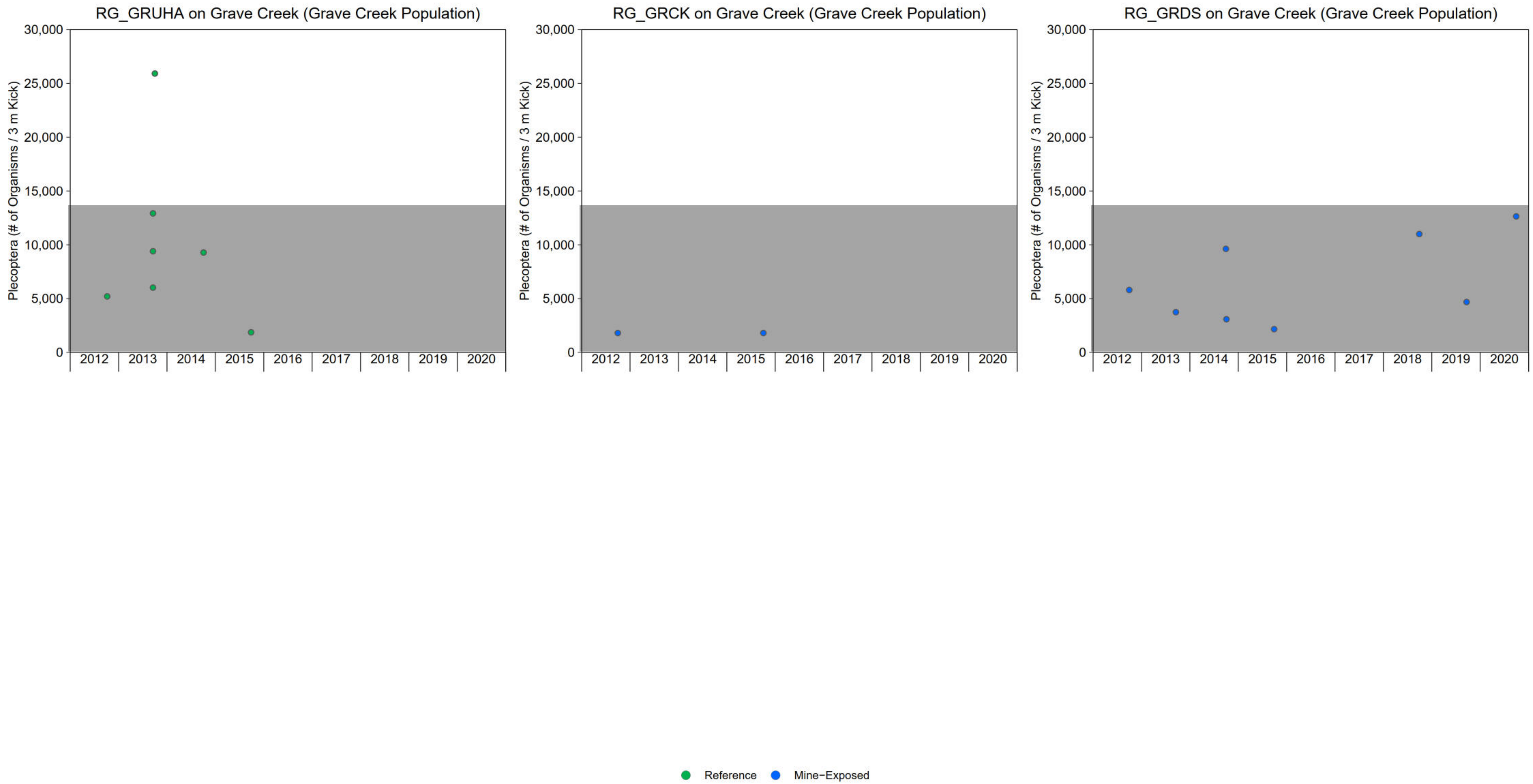

Figure A.7: Plecopteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

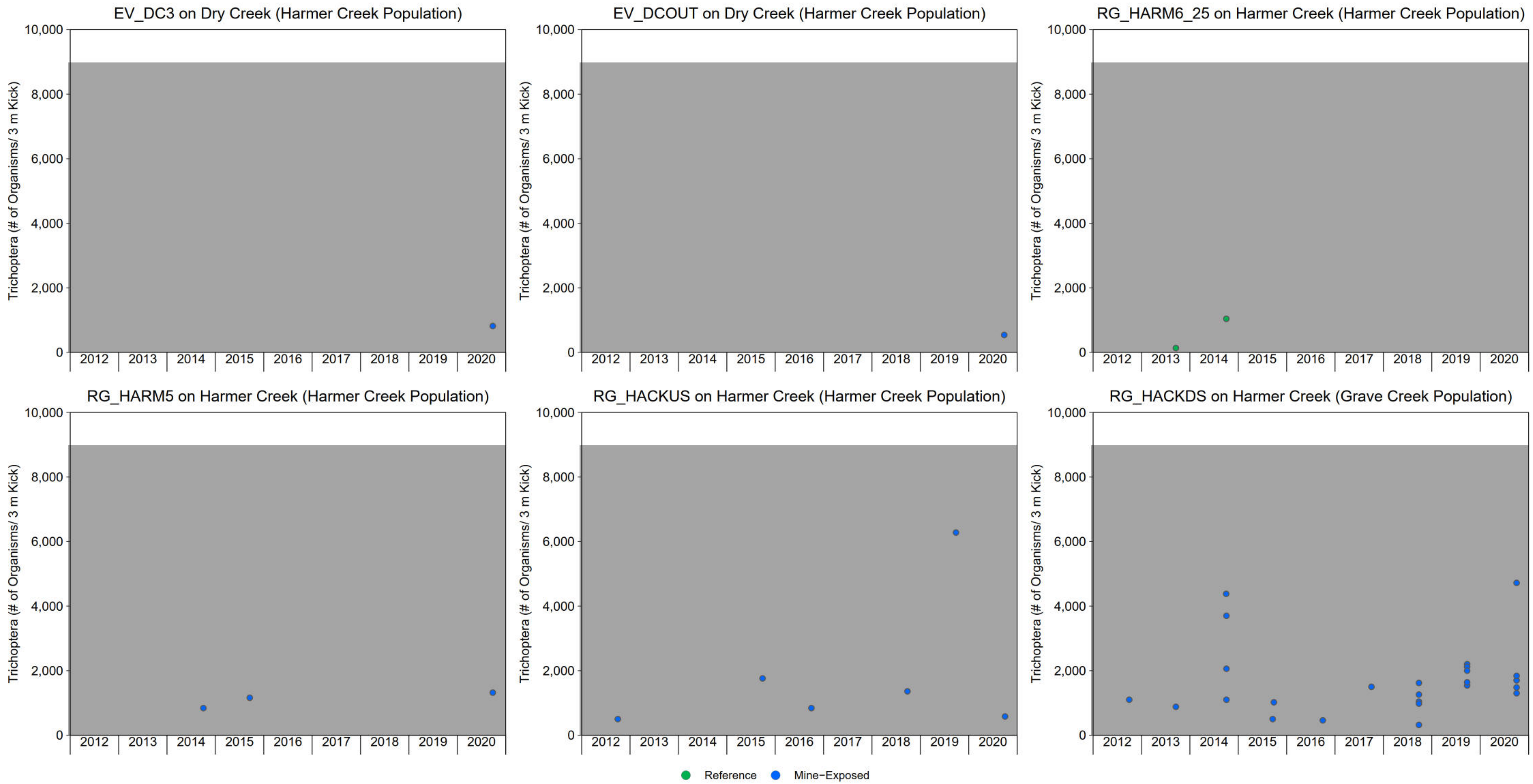

Figure A.8: Trichopteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

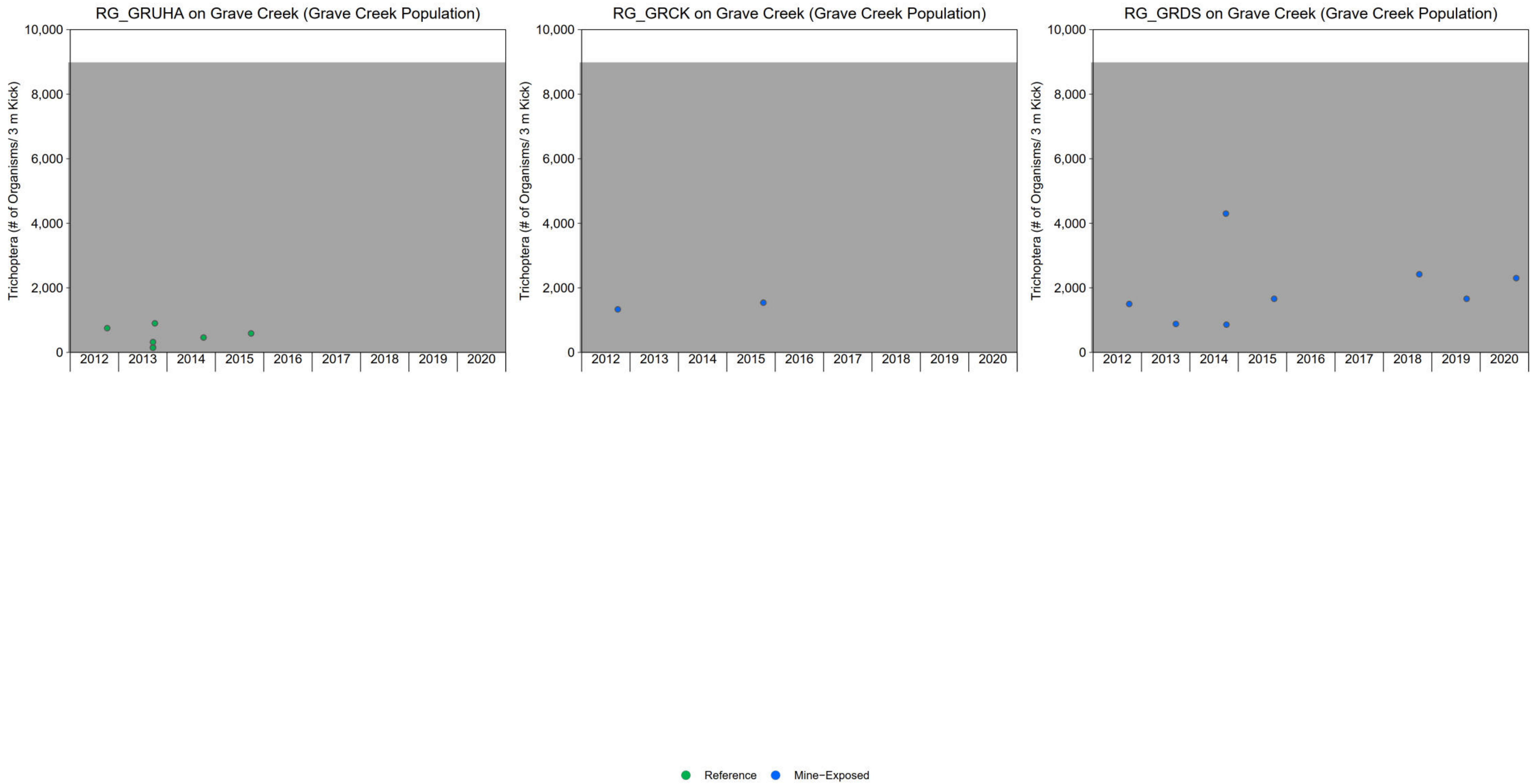

Figure A.8: Trichopteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

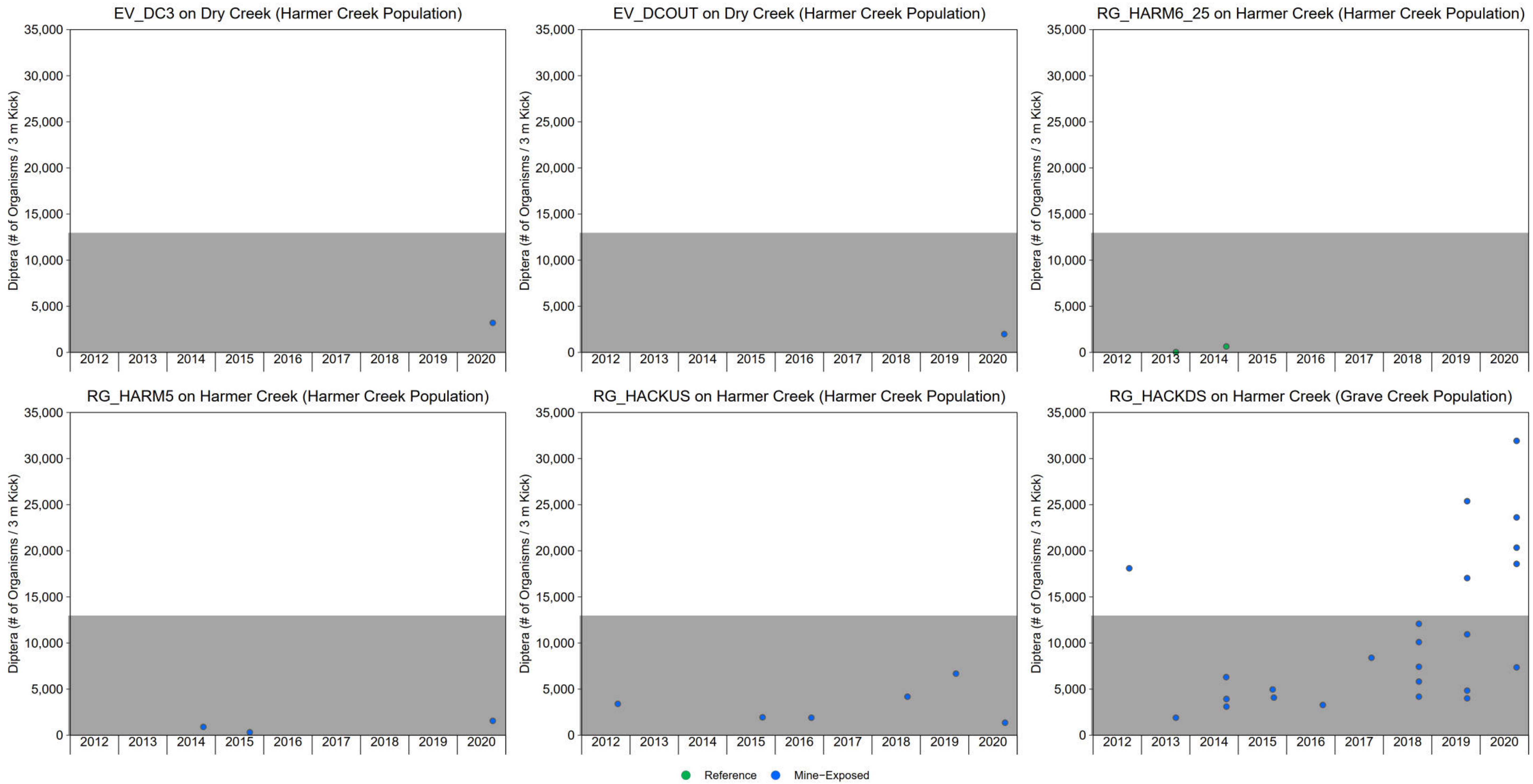

Figure A.9: Dipteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

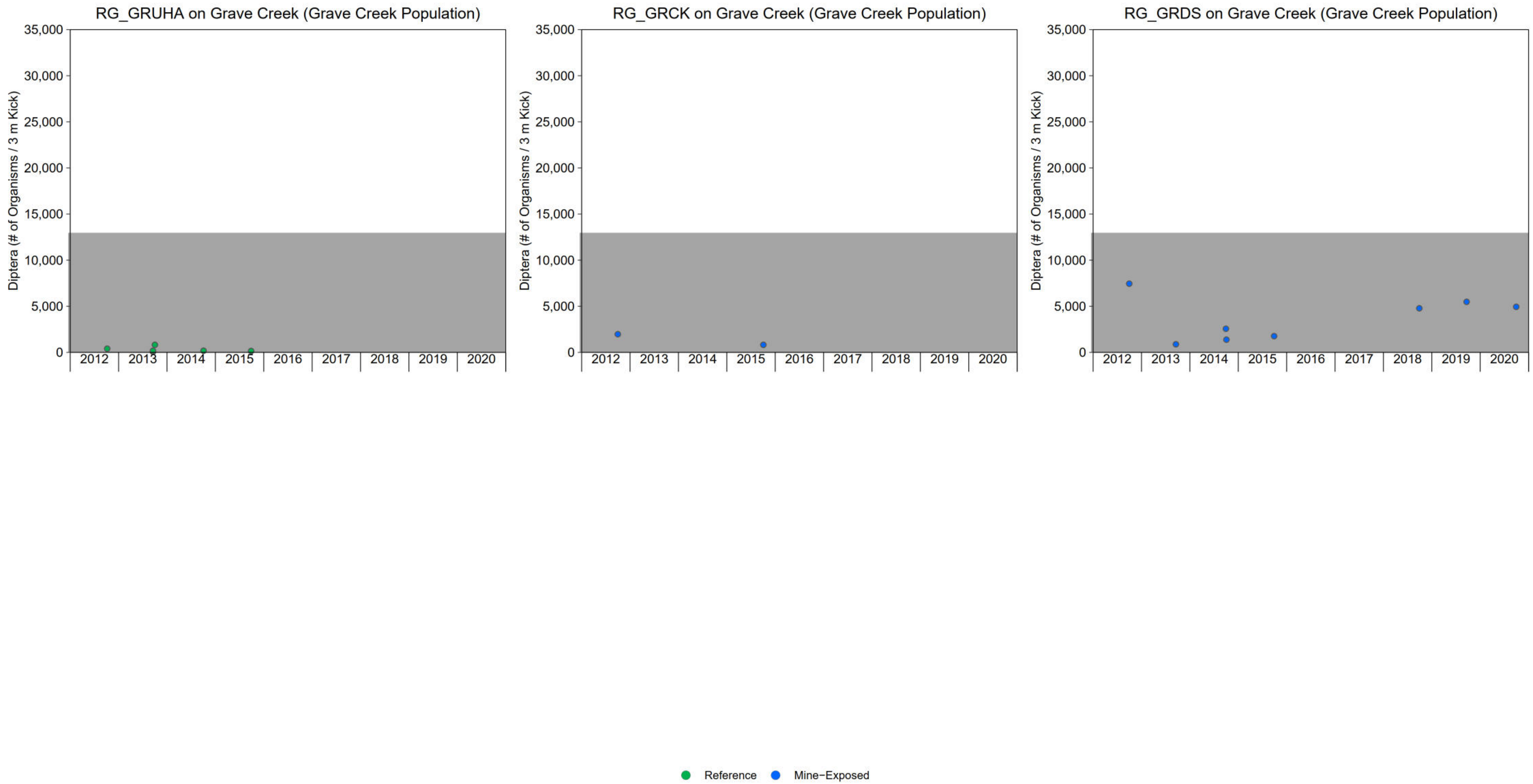

Figure A.9: Dipteran Abundance at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

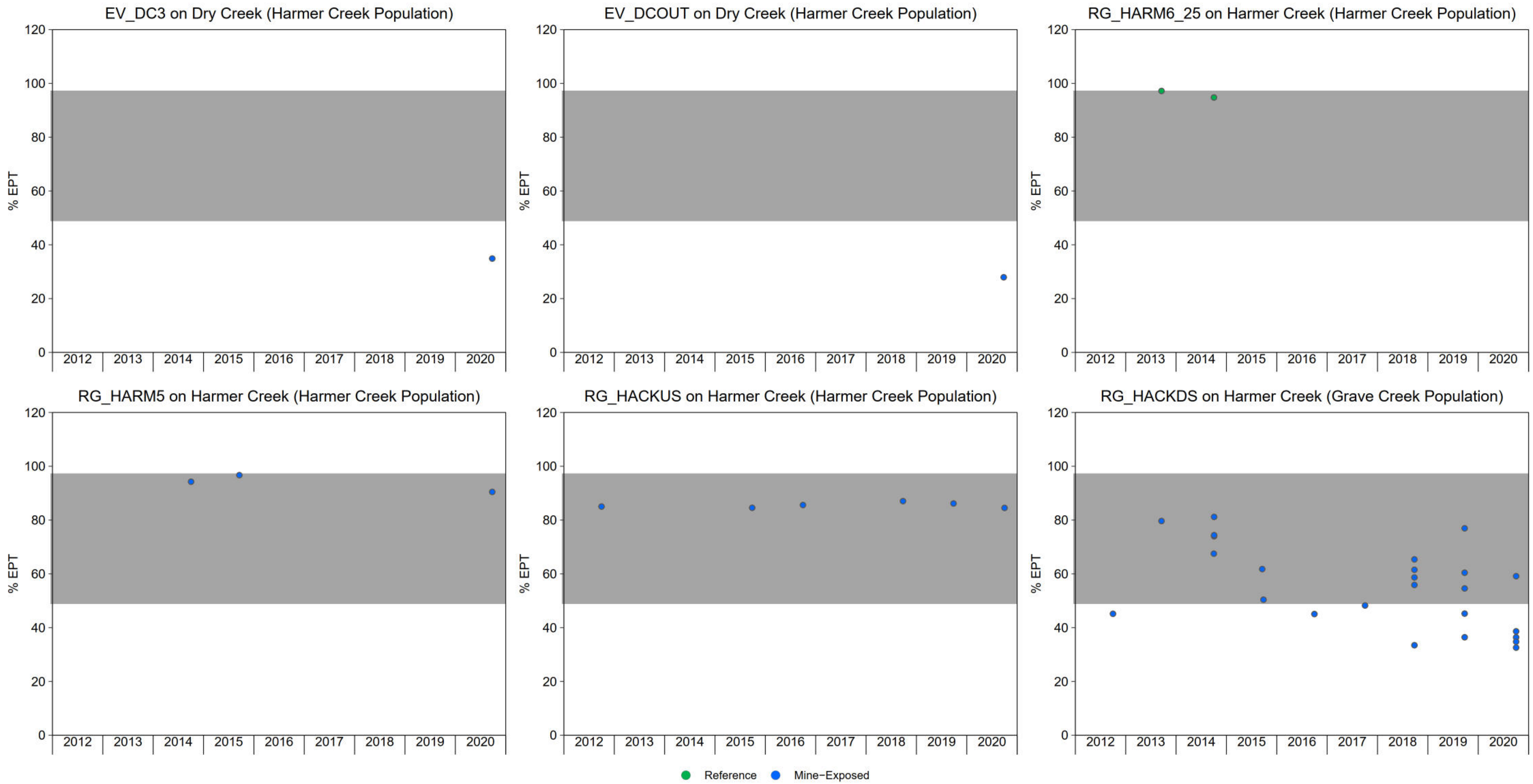

Figure A.10: Proportions of Ephemeroptera, Plecoptera, and Trichoptera (Combined) at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

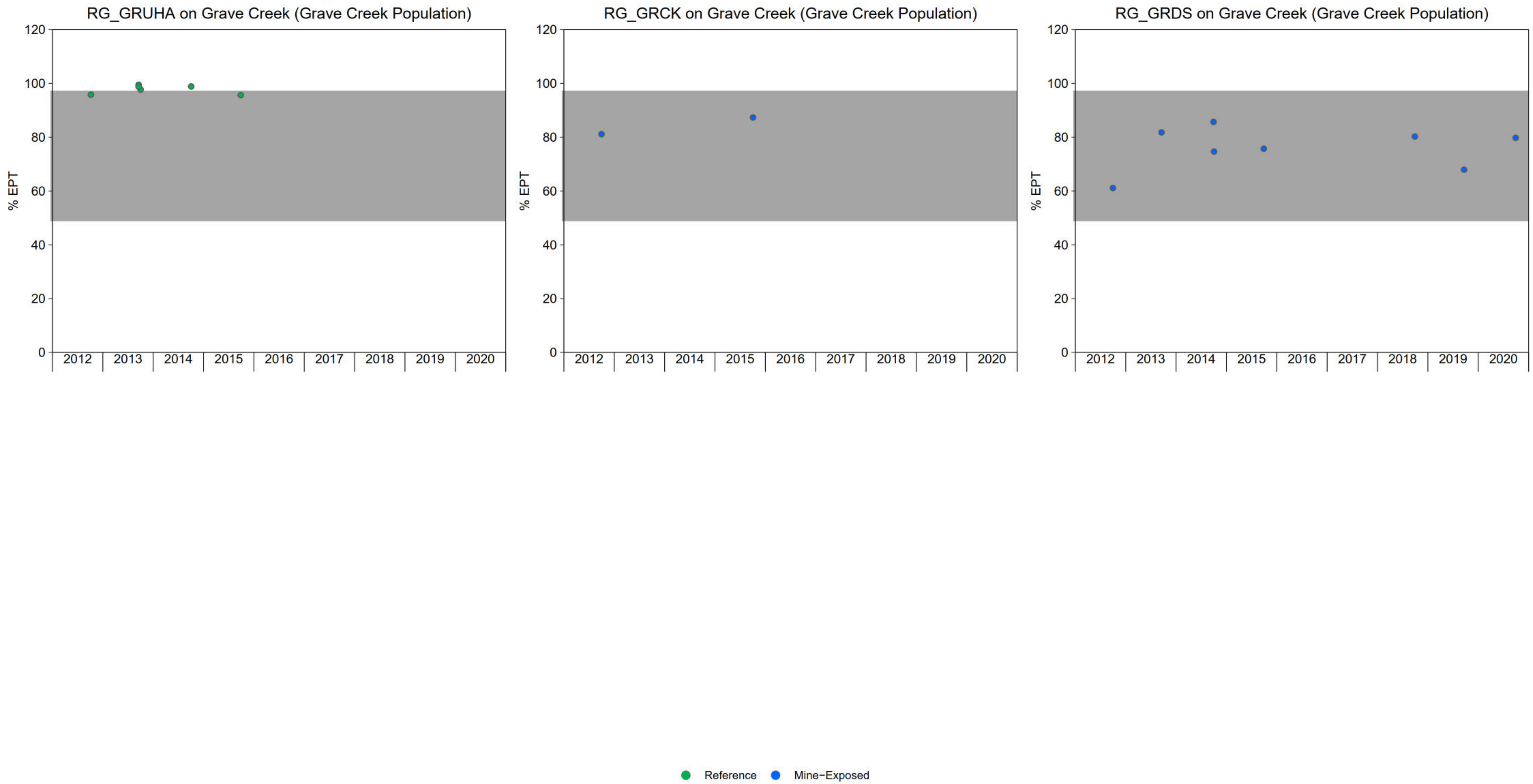

Figure A.10: Proportions of Ephemeroptera, Plecoptera, and Trichoptera (Combined) at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

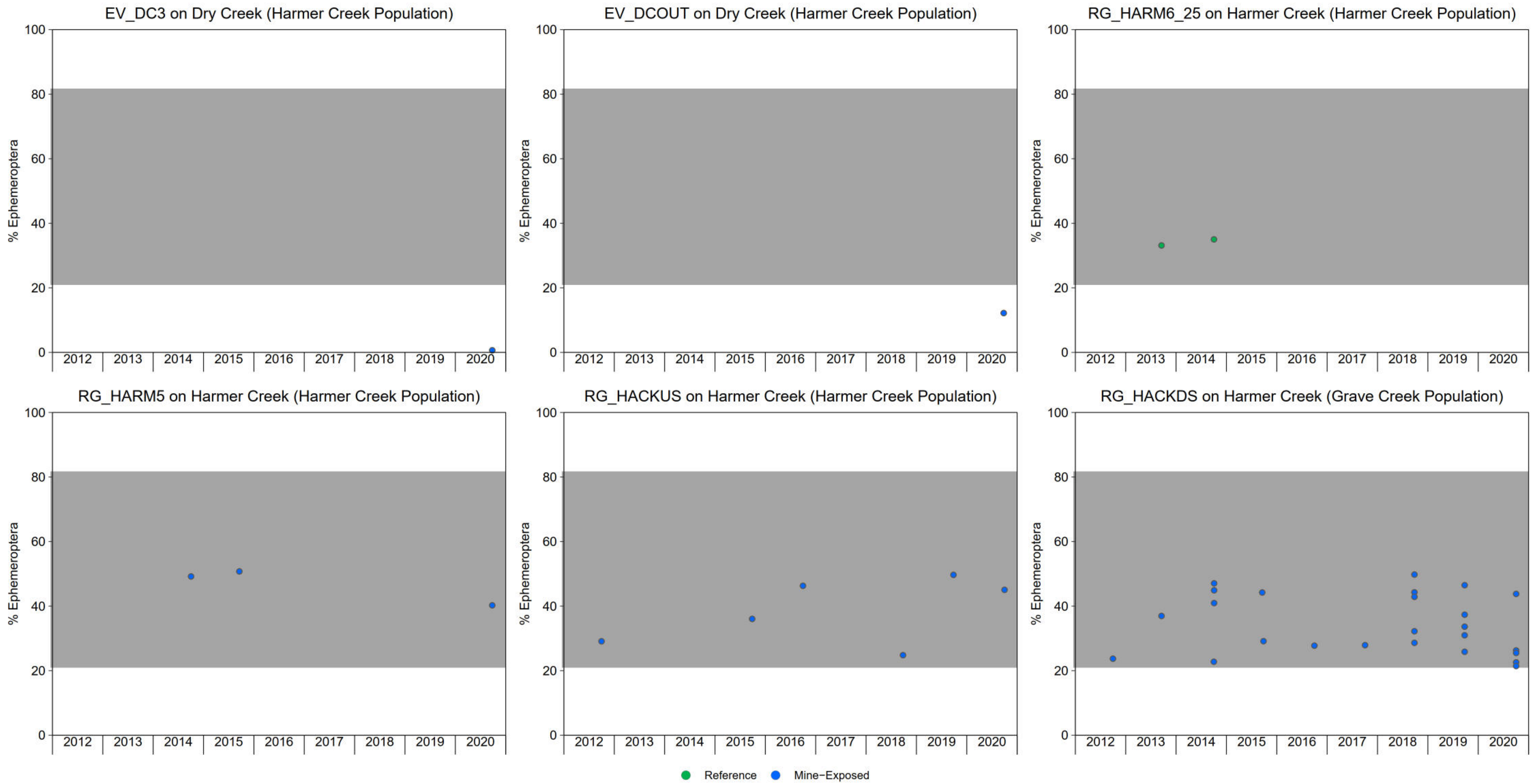

Figure A.11: Proportions of Ephemeroptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

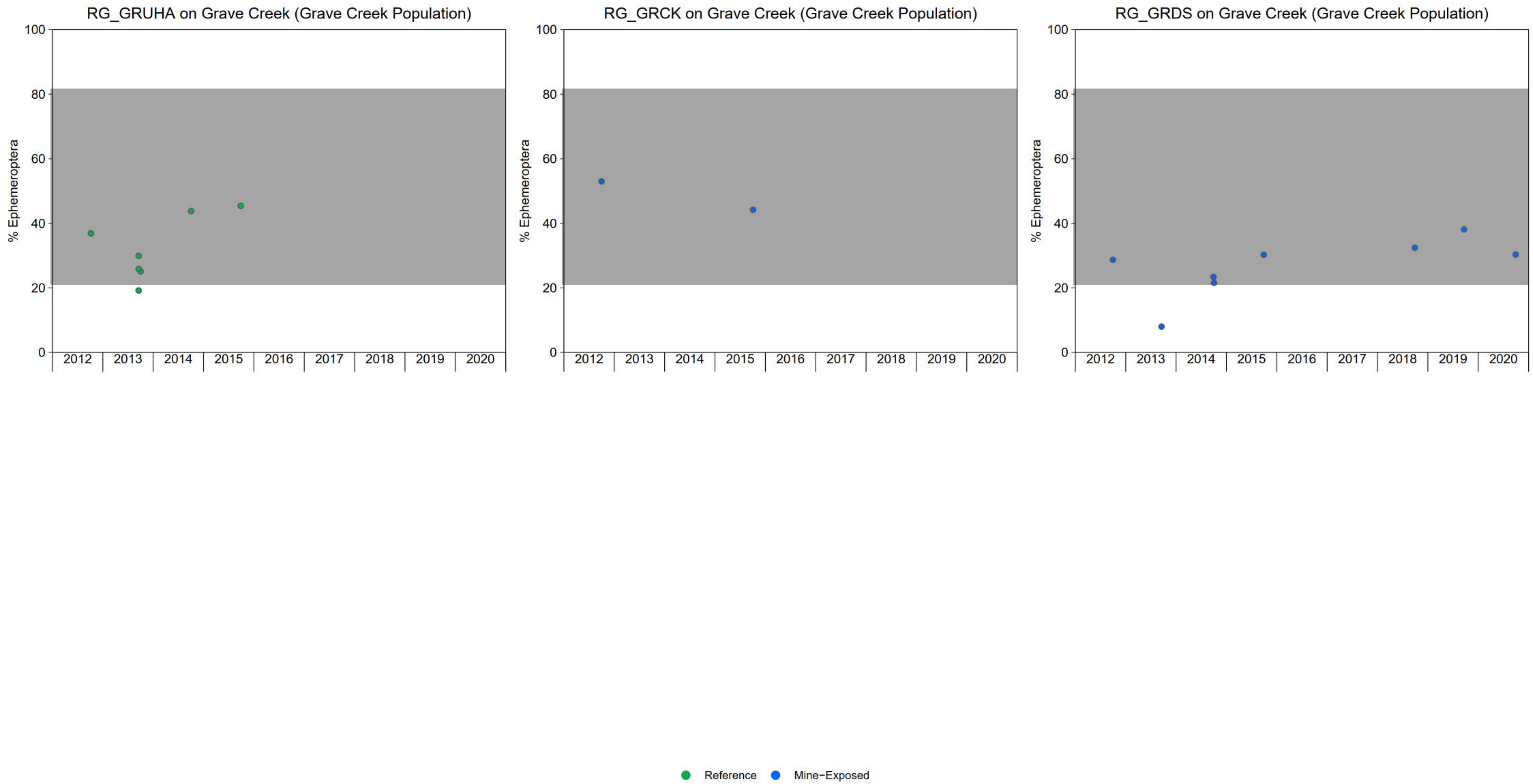

Figure A.11: Proportions of Ephemeroptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

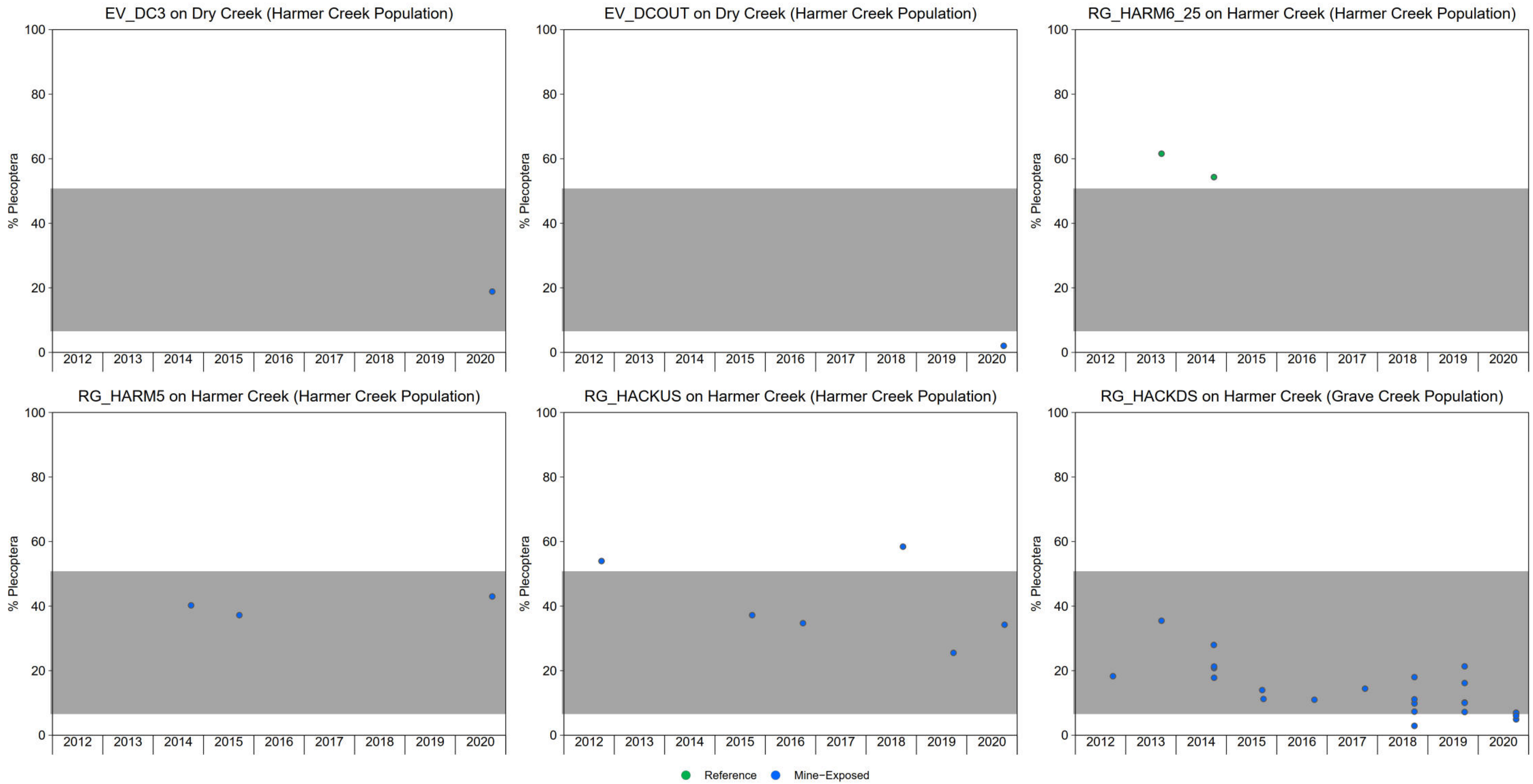

Figure A.12: Proportions of Plecoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

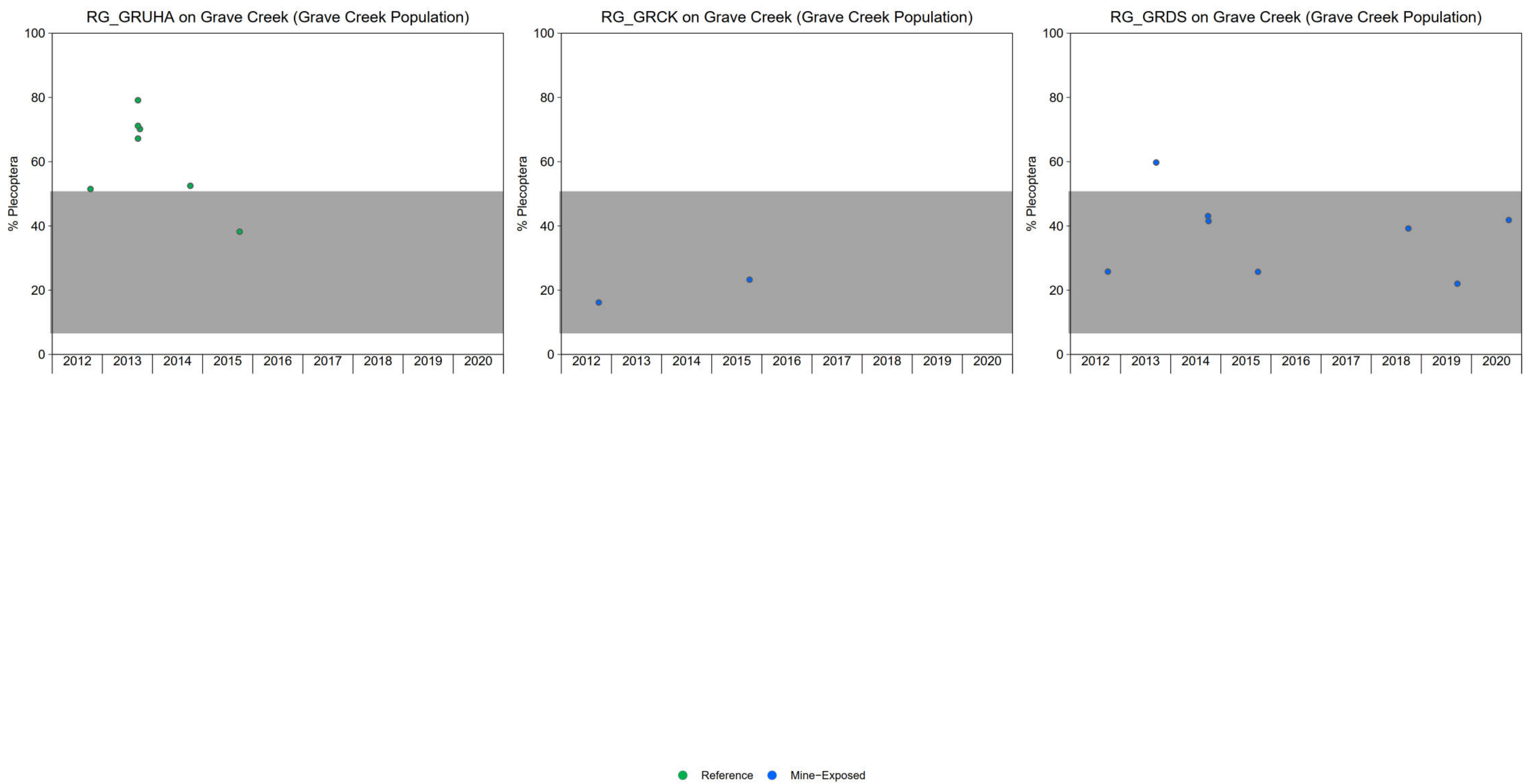

Figure A.12: **Proportions of Plecoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020**

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

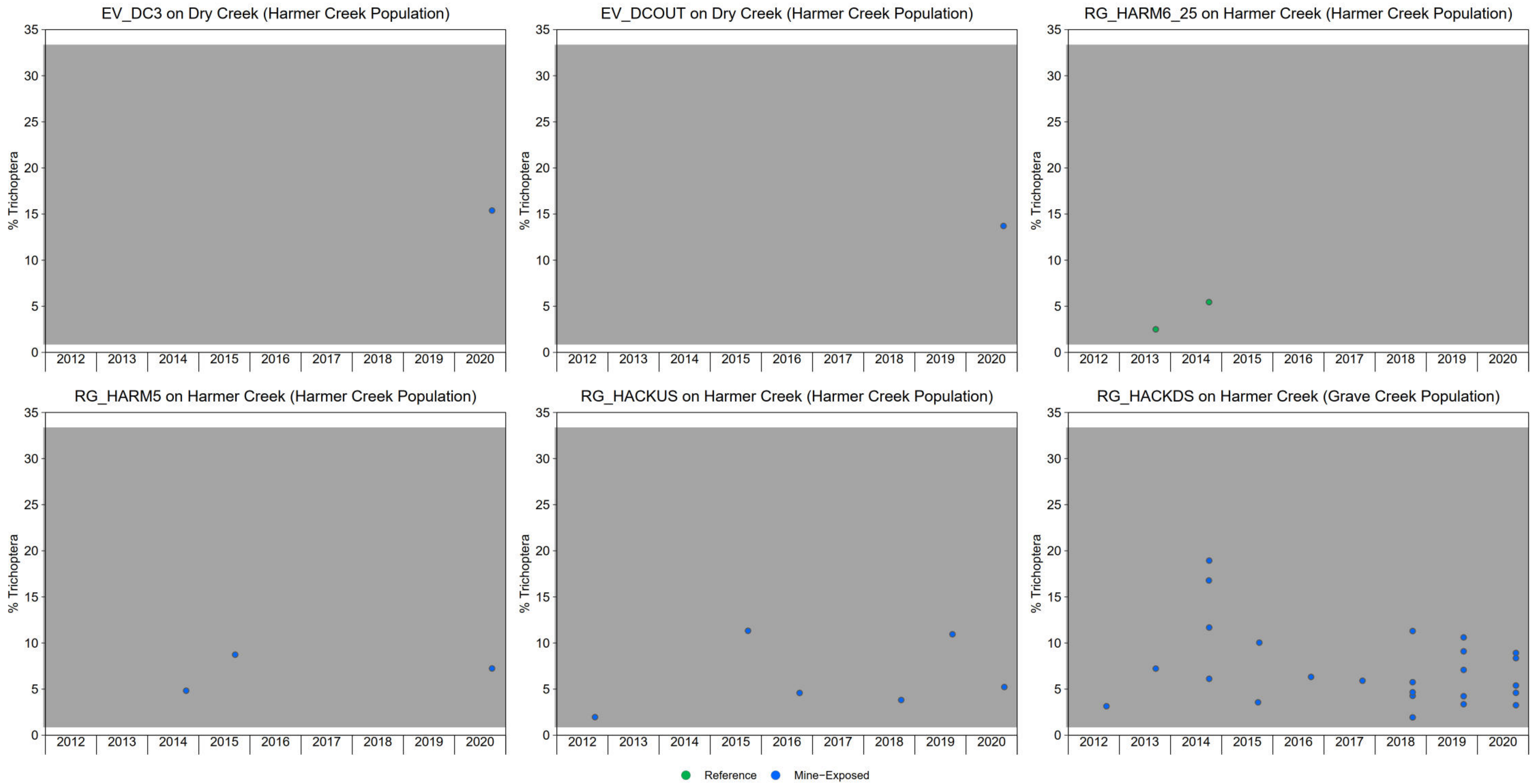

Figure A.13: Proportions of Trichoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

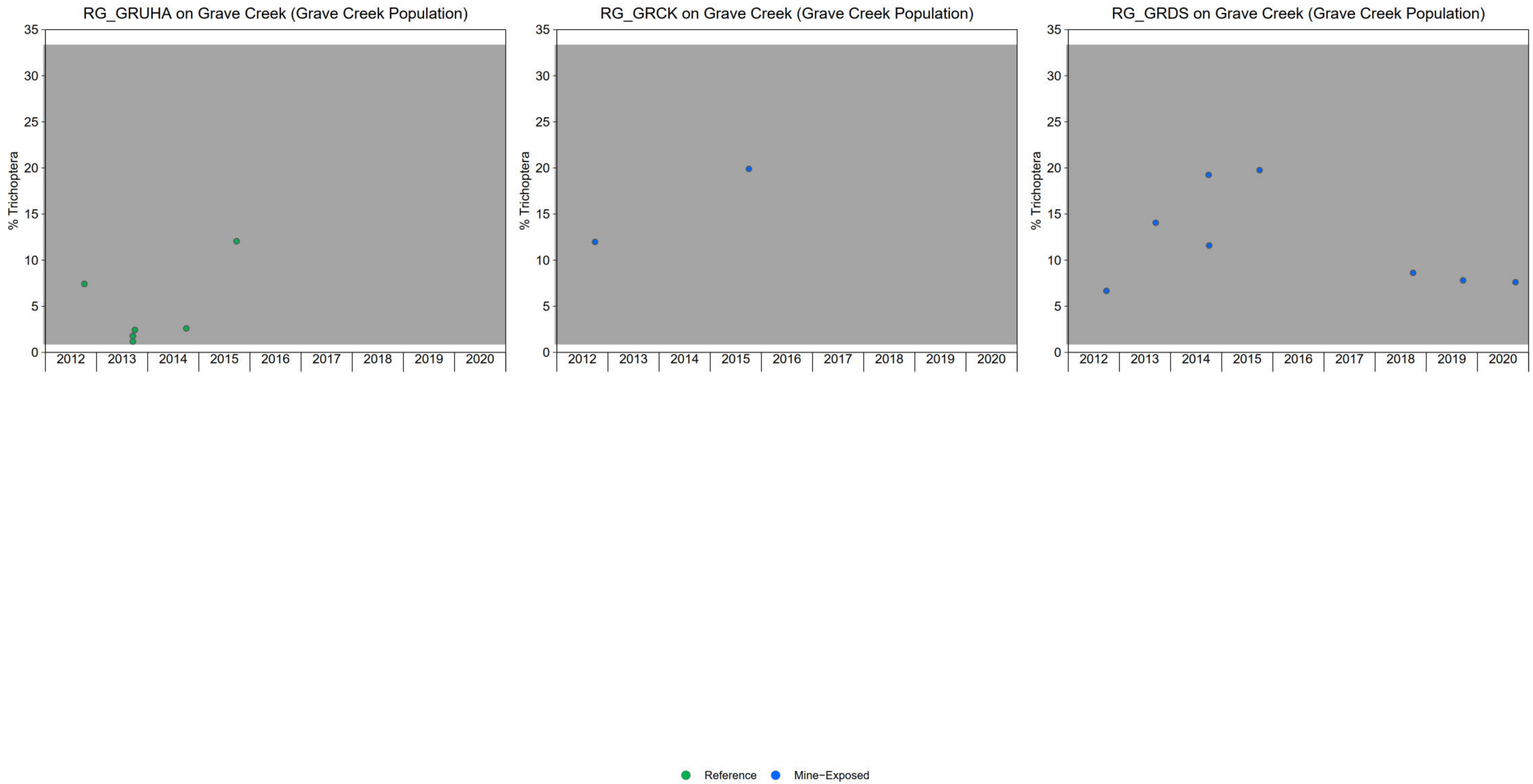

Figure A.13: Proportions of Trichoptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

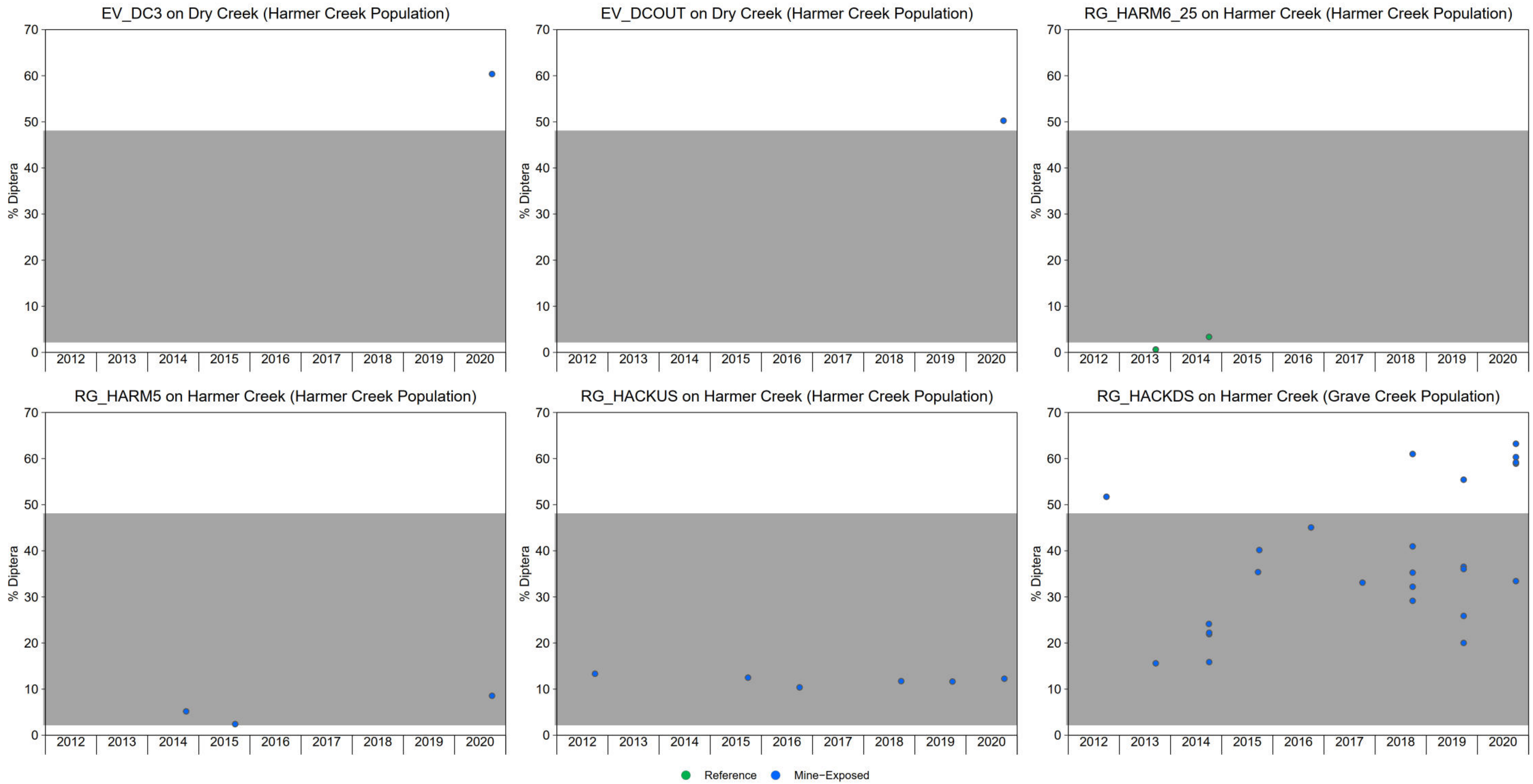

Figure A.14: Proportions of Diptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

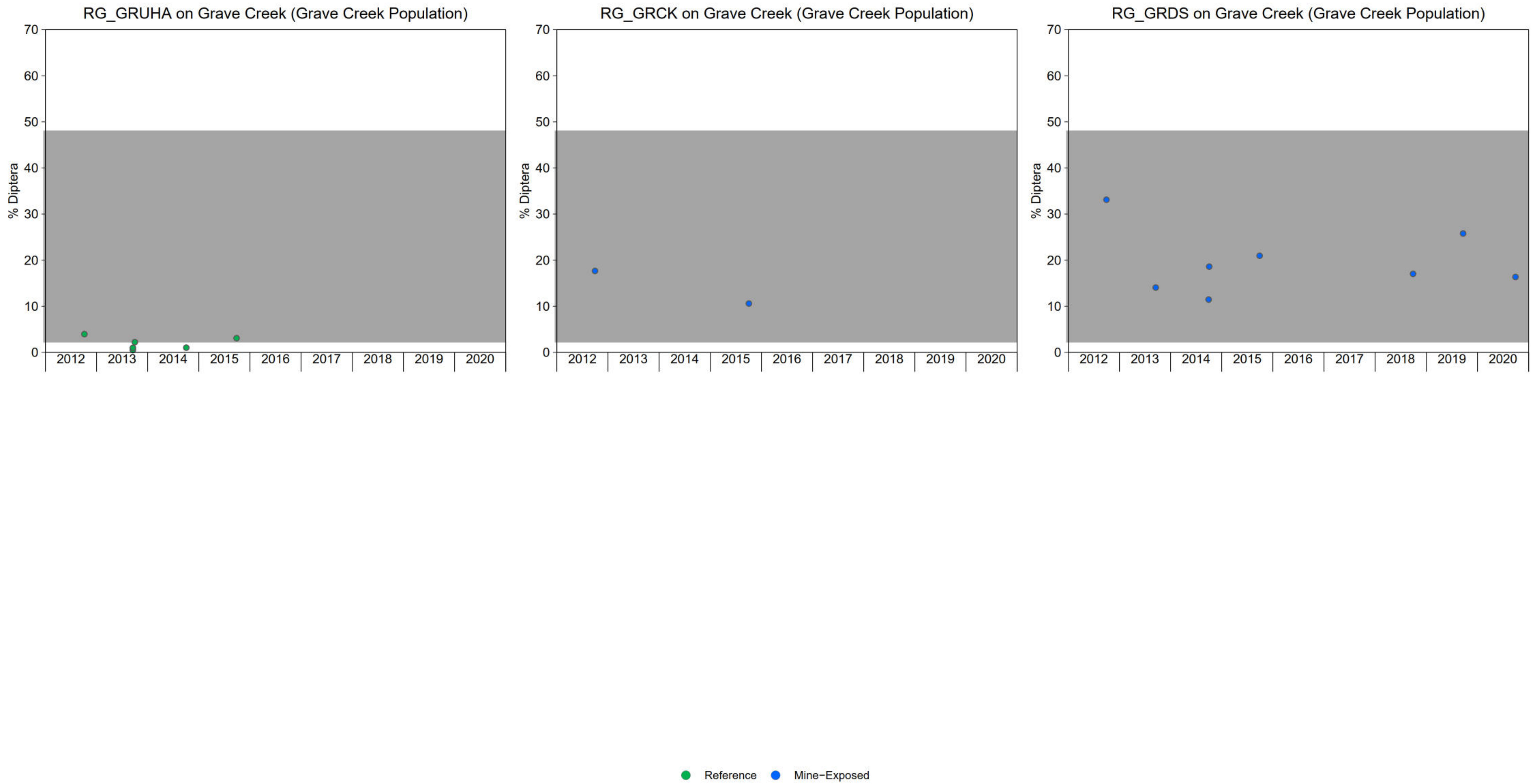

Figure A.14: Proportions of Diptera at Individual Sampling Locations in the Harmer Creek and Grave Creek Population Areas, 2012 to 2020

Notes: Grey shading = regional reference area normal ranges (based on data collected from 2012 to 2019 as part of the Regional Aquatic Effects Monitoring Program [RAEMP]; Minnow 2020).

Table A.1: Summary Statistics for Length, Weight, and Condition of Westslope Cutthroat Trout from the Harmer Creek and Grave Creek Populations, 1996 to 2020

Group	Year	Population	Parameter	N	Mean	SD	SE	Min	Median	Max
Juvenile	2008	Grave	Fork length (mm)	6	107	41.6	17.0	69.0	95.5	165
			Weight (g)	6	20.7	21.8	8.90	4.00	10.5	57.0
			Fulton's K	6	1.20	0.104	0.0424	0.999	1.23	1.29
		Harmer	Fork length (mm)	11	107	11.4	3.43	89.0	109	128
			Weight (g)	11	15.4	4.82	1.45	8.00	15.0	25.0
			Fulton's K	11	1.24	0.0983	0.0296	1.13	1.24	1.40
	2013	Grave	Fork length (mm)	8	134	24.4	8.62	100	140	165
			Weight (g)	8	31.0	16.3	5.77	10.7	30.1	55.7
			Fulton's K	8	1.17	0.101	0.0355	0.996	1.22	1.27
		Harmer	Fork length (mm)	11	124	28.0	8.45	82.0	123	169
			Weight (g)	11	25.3	16.2	4.89	5.60	19.5	52.9
			Fulton's K	11	1.15	0.174	0.0525	0.949	1.17	1.42
	2017	Grave	Fork length (mm)	107	122	28.9	2.79	66.0	125	167
			Weight (g)	107	26.3	21.3	2.06	3.00	21.0	145
			Fulton's K	107	1.19	0.368	0.0355	0.772	1.14	4.13
		Grave (Outliers Removed)	Fork length (mm)	105	121	28.8	2.81	66.0	122	167
			Weight (g)	105	24.5	16.5	1.61	3.00	19.0	60.0
			Fulton's K	105	1.15	0.178	0.0174	0.772	1.13	1.65
		Harmer	Fork length (mm)	124	128	25.6	2.30	69.0	130	169
			Weight (g)	124	27.4	16.0	1.44	3.00	24.9	70.0
			Fulton's K	124	1.15	0.163	0.0146	0.671	1.12	1.96
		Harmer (Outliers Removed)	Fork length (mm)	121	127	25.6	2.33	69.0	128	169
			Weight (g)	121	26.8	15.5	1.41	3.00	24.8	70.0
			Fulton's K	121	1.14	0.128	0.0117	0.913	1.12	1.61
	2018	Grave	Fork length (mm)	88	110	24.9	2.65	67.0	108	163
			Weight (g)	88	16.6	10.9	1.16	2.90	14.0	51.0
			Fulton's K	88	1.08	0.0794	0.00847	0.920	1.07	1.31
		Harmer	Fork length (mm)	28	129	30.5	5.76	66.0	138	166
			Weight (g)	28	27.4	15.2	2.88	2.40	29.4	54.3
			Fulton's K	28	1.09	0.107	0.0201	0.835	1.10	1.26
	2019	Grave	Fork length (mm)	68	120	26.7	3.23	66.0	122	163
			Weight (g)	68	22.3	13.1	1.59	3.30	20.6	53.3
			Fulton's K	68	1.12	0.0885	0.0107	0.944	1.10	1.33
		Harmer [a]	Fork length (mm)	3	154	12.9	7.45	143	150	168
			Weight (g)	3	42.2	13.3	7.68	34.4	34.7	57.6
			Fulton's K	3	1.14	0.106	0.0610	1.02	1.19	1.21
	2020	Grave	Fork length (mm)	45	118	25.7	3.83	77.0	118	163
			Weight (g)	45	23.2	16.1	2.41	5.80	17.9	61.8
			Fulton's K	45	1.21	0.277	0.0412	0.766	1.17	2.63
		Grave (Outliers Removed)	Fork length (mm)	44	118	25.9	3.91	77.0	118	163
			Weight (g)	44	22.3	15.2	2.29	5.80	17.4	55.4
			Fulton's K	44	1.18	0.175	0.0264	0.766	1.16	1.69
		Harmer [a]	Fork length (mm)	5	129	21.1	9.45	101	125	157
			Weight (g)	5	25.9	11.5	5.13	12.2	23.0	43.0
			Fulton's K	5	1.16	0.0570	0.0255	1.09	1.18	1.23
Adults [b]	1996	Harmer	Fork length (mm)	1	245	-	-	245	245	245
			Weight (g)	1	200	-	-	200	200	200
			Fulton's K	1	1.36	-	-	1.36	1.36	1.36
	2008	Grave	Fork length (mm)	1	177	-	-	177	177	177
			Weight (g)	1	83.0	-	-	83.0	83.0	83.0
			Fulton's K	1	1.50	-	-	1.50	1.50	1.50
	2013	Grave	Fork length (mm)	4	193	13.3	6.65	174	196	205
			Weight (g)	4	98.6	19.9	9.98	71.7	102	119
			Fulton's K	4	1.36	0.0813	0.0407	1.26	1.37	1.45
		Harmer	Fork length (mm)	4	198	10.9	5.44	183	199	209
			Weight (g)	4	101	17.2	8.59	76.2	105	116
			Fulton's K	4	1.30	0.0472	0.0236	1.24	1.30	1.35
	2017	Grave	Fork length (mm)	70	205	38.5	4.60	171	193	383
			Weight (g)	70	128	121	14.5	49.0	93.5	740
			Fulton's K	70	1.29	0.138	0.0165	0.948	1.30	1.67
		Harmer	Fork length (mm)	84	203	27.5	3.00	170	195	320
			Weight (g)	84	115	56.6	6.17	60.0	95.0	380
			Fulton's K	84	1.31	0.158	0.0172	1.03	1.30	1.89
	2018	Grave	Fork length (mm)	35	207	19.1	3.23	170	206	251
			Weight (g)	35	110	33.8	5.71	50.8	107	195
			Fulton's K	35	1.21	0.0981	0.0166	1.01	1.20	1.40
		Harmer	Fork length (mm)	25	203	26.1	5.21	170	193	282
			Weight (g)	25	112	49.7	9.94	60.9	94.0	291
			Fulton's K	25	1.27	0.0768	0.0154	1.10	1.28	1.40
	2019	Grave	Fork length (mm)	13	188	16.8	4.66	173	183	228
			Weight (g)	13	80.6	24.0	6.65	54.0	74.5	128
			Fulton's K	13	1.18	0.106	0.0294	1.04	1.14	1.36
		Harmer	Fork length (mm)	9	207	25.6	8.54	172	203	243
			Weight (g)	9	114	54.0	18.0	47.2	89.0	209
			Fulton's K	9	1.20	0.164	0.0547	0.928	1.21	1.46
	2020	Grave	Fork length (mm)	15	209	24.1	6.21	172	204	262
			Weight (g)	15	113	40.0	10.3	65.9	105	201
			Fulton's K	15	1.20	0.126	0.0326	0.955	1.20	1.50
		Harmer	Fork length (mm)	9	233	29.8	9.94	185	237	282
			Weight (g)	9	174	83.3	27.8	63.0	169	320
			Fulton's K	9	1.27	0.167	0.0557	0.995	1.27	1.47

Notes: N = number; SD = standard deviation; SE = standard error; Min = minimum; Max = maximum; mm = millimetres; g = grams; Fulton's K = Fulton's condition factor; ≥ = greater than or equal to, - = no relevant data.

[a] Juvenile fish captured from the Harmer Creek population area in 2019 and 2020 were age-2+.

[b] Harmer and Grave Westslope Cutthroat Trout with fork lengths ≥170 mm were classified as adults.

Table A.2: Comparisons of Weight-at-Length for Juvenile and Adult Westslope Cutthroat Trout from the Harmer and Grave Creek Populations, 2008 to 2020

Group	Treatment of Outliers	Year	Sample Size [a]	Test	P-value	Mean Fork Length (Covariate) (cm) [c]	Summary Statistic Type [d]	Mean Body Weight (Response Variable) (g)	
					Main Effect [b] Population			Harmer Creek Population	Grave Creek Population
Juvenile	Removed	2008	17	ANCOVA	0.724	121	Adjusted Mean	19.9	19.8
		2013	19					18.5	18.4
		2017	227					20.1	20.0
		2018	116					19.3	19.2
		2019	68					-	-
		2020	48					21.3	21.2
	Retained	2008	17	ANCOVA	0.572	121	Adjusted Mean	19.6	19.8
		2013	19					18.2	18.4
		2017	231					20.3	20.5
		2018	116					19.4	19.5
		2019	68					-	-
		2020	50					21.5	21.7
Adult	Removed	2013	8	ANCOVA	0.043	205	Adjusted Mean	114	111
		2017	154					110	107
		2018	60					106	103
		2019	22					104	101
		2020	24					106	103
	Retained	2013	8	ANCOVA	0.043	205	Adjusted Mean	114	111
		2017	154					110	107
		2018	60					106	103
		2019	22					104	101
		2020	24					106	103

Main Effect P-value <0.1

Notes: cm = centimetres; g = grams; ANCOVA = Analysis of Covariance; - = no data or insufficient data for inclusion in the analysis (i.e., sample sizes less than or equal to four for juveniles in 2019); < = less than. No interactions were retained in the final models for juveniles or adults.

[a] Pooled sample sizes for the Harmer Creek and Grave Creek populations.

[b] The full model used for analysis included *Year* as a main effect and *Day of Year* and *Fork Length* as covariates. In all cases, all variables were significant. P-values are not displayed because variables were included to control for variation but are not focal comparisons. Details for comparisons among years can be found in Tables A.3 and A.4.

[c] The mean value of the *Fork Length* covariate (that corresponds to the adjusted means for the response variable) for the parallel slope ANCOVA model.

[d] The estimated marginal means from the ANCOVA model for mean length of individuals on September 15th of the respective year.

Table A.3: Comparisons of Weight-at-Length for Juvenile and Adult Westslope Cutthroat Trout from the Harmer Creek Population, 2008 to 2020

Group	Treatment of Outliers	Year	Sample Size [a]	Mean Body Weight (Response Variable) (g)	Year P-value [b]	Post-hoc Contrasts and MOD [c]									
						2013		2017		2018		2019		2020	
						P-value	MOD	P-value	MOD	P-value	MOD	P-value	MOD	P-value	MOD
Juvenile	Removed	2008	11	19.9	<0.001	0.373	-6.8	0.999	1.2	0.945	-2.8	-	-	0.383	7.0
		2013	11	18.5		nc	nc	0.049	8.6	0.732	4.3	-	-	<0.001	15
		2017	122	20.1		nc	nc	nc	nc	0.023	-3.9	-	-	0.024	5.8
		2018	28	19.3		nc	nc	nc	nc	nc	nc	-	-	<0.001	10
		2019	-	-		nc	nc	nc	nc	nc	nc	nc	nc	-	-
		2020	5	21.3		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
	Retained	2008	11	19.6	<0.001	0.577	-7.1	0.932	3.7	>0.999	-1.3	-	-	0.289	9.6
		2013	11	18.2		nc	nc	0.026	12	0.580	6.3	-	-	0.001	18
		2017	124	20.3		nc	nc	nc	nc	0.030	-4.8	-	-	0.127	5.7
		2018	28	19.4		nc	nc	nc	nc	nc	nc	-	-	<0.001	11
		2019	-	-		nc	nc	nc	nc	nc	nc	nc	nc	-	-
		2020	5	21.5		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Adult	Removed	2013	4	114	0.013	nc	nc	0.939	-2.9	0.339	-7.0	0.272	-8.4	0.542	-6.6
		2017	84	110		nc	nc	nc	nc	0.046	-4.3	0.136	-5.7	0.526	-3.8
		2018	25	106		nc	nc	nc	nc	nc	nc	0.981	-1.5	>0.999	0.51
		2019	9	104		nc	nc	nc	nc	nc	nc	nc	nc	0.966	2.0
		2020	9	106		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
	Retained	2013	4	114	0.013	nc	nc	0.939	-2.9	0.339	-7.0	0.272	-8.4	0.542	-6.6
		2017	84	110		nc	nc	nc	nc	0.046	-4.3	0.136	-5.7	0.526	-3.8
		2018	25	106		nc	nc	nc	nc	nc	nc	0.981	-1.5	>0.999	0.51
		2019	9	104		nc	nc	nc	nc	nc	nc	nc	nc	0.966	2.0
		2020	9	106		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc

Year or Population P-value <0.1. (grey shading)

MOD >10%. (blue shading)

Notes: g = grams; MOD = Magnitude of Difference; < = less than; > = greater than; - = no data or insufficient data for inclusion in the analysis (i.e., sample sizes less than or equal to four for juveniles in 2019); nc = no relevant comparison; % = percent.
No interactions were retained in the final models for juveniles or adults.

[a] Sample sizes are specific to the Harmer Creek population.

[b] The full model also included *Population* as a main effect (see Table A.2) and *Day of Year* and *Fork Length* as covariates. P-values are not displayed because variables were included to control for variation but are not focal comparisons. Both the *Day of the Year* and *Fork Length* covariates were significant, whereas *Population* had no significant effect.

[c] The MOD was calculated as the latter year (columns) - the earlier year (rows) divided by the earlier year (rows) x 100%.

Table A.4: Comparisons of Weight-at-Length for Juvenile and Adult Westslope Cutthroat Trout from the Grave Creek Population, 2008 to 2020

Group	Treatment of Outliers	Year	Sample Size [a]	Mean Body Weight (Response Variable) (g)	Year P-value [b]	Post-hoc Contrasts and MOD [c]									
						2013		2017		2018		2019		2020	
						P-value	MOD	P-value	MOD	P-value	MOD	P-value	MOD	P-value	MOD
Juvenile	Removed	2008	6	19.8	<0.001	0.373	-6.8	0.999	1.2	0.945	-2.8	0.948	3.2	0.383	7.0
		2013	8	18.4		nc	nc	0.049	8.6	0.732	4.3	0.031	11	<0.001	15
		2017	105	20.0		nc	nc	nc	nc	0.023	-3.9	0.843	2.0	0.024	5.8
		2018	88	19.2		nc	nc	nc	nc	nc	nc	0.007	6.2	<0.001	10
		2019	68	20.4		nc	nc	nc	nc	nc	nc	nc	nc	0.485	3.7
		2020	43	21.2		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
	Retained	2008	6	19.8	<0.001	0.577	-7.1	0.932	3.7	>0.999	-1.3	0.861	5.2	0.289	9.6
		2013	8	18.4		nc	nc	0.026	12	0.580	6.3	0.038	13	0.001	18
		2017	107	20.5		nc	nc	nc	nc	0.030	-4.8	0.983	1.5	0.127	5.7
		2018	88	19.5		nc	nc	nc	nc	nc	nc	0.042	6.5	<0.001	11
		2019	68	20.8		nc	nc	nc	nc	nc	nc	nc	nc	0.584	4.2
		2020	45	21.7		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
Adult	Removed	2013	4	111	0.013	nc	nc	0.939	-2.9	0.339	-7.0	0.272	-8.4	0.542	-6.6
		2017	70	107		nc	nc	nc	nc	0.046	-4.3	0.136	-5.7	0.526	-3.8
		2018	35	103		nc	nc	nc	nc	nc	nc	0.981	-1.5	>0.999	0.51
		2019	13	101		nc	nc	nc	nc	nc	nc	nc	nc	0.966	2.0
		2020	15	103		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc
	Retained	2013	4	111	0.013	nc	nc	0.939	-2.9	0.339	-7.0	0.272	-8.4	0.542	-6.6
		2017	70	107		nc	nc	nc	nc	0.046	-4.3	0.136	-5.7	0.526	-3.8
		2018	35	103		nc	nc	nc	nc	nc	nc	0.981	-1.5	>0.999	0.51
		2019	13	101		nc	nc	nc	nc	nc	nc	nc	nc	0.966	2.0
		2020	15	103		nc	nc	nc	nc	nc	nc	nc	nc	nc	nc

[grey] Year or Population P-value <0.1.

[blue] MOD >10%.

Notes: g = grams; MOD = Magnitude of Difference; < = less than; > = greater than; nc = no relevant comparison; % = percent. No interactions were retained in the final models for juveniles or adults.

[a] Sample sizes are specific to the Grave Creek population.

[b] The full model also included *Population* as a main effect (see Table A.2) and *Day of Year* and *Fork Length* as covariates. P-values are not displayed because variables were included to control for variation but are not focal comparisons. Both the *Day of the Year* and *Fork Length* covariates were significant, whereas *Population* had no significant effect.

[c] The MOD was calculated as the latter year (columns) - the earlier year (rows) divided by the earlier year (rows) x 100%.

Table A.5: Summary of Benthic Invertebrate Endpoints Collected by Kick and Sweep Sampling at Dry, Harmer, and Grave Creeks, 2012 to 2020

Westslope Cutthroat Trout Population Area	Status	Area ID	Year	Replicate Number	Abundance (No. of Organisms/ 3-min Kick)						Proportions				
					Total	EPT	Ephemeroptera	Plecoptera	Trichoptera	Diptera	%EPT	%Ephemeroptera	%Plecoptera	%Trichoptera	%Diptera
Harmer Creek	Reference	HARM6_25	2013	1	5,333	5,183	1,767	3,283	133	33	97%	33%	62%	2.5%	0.63%
			2014	1	19,080	18,080	6,680	10,360	1,040	640	95%	35%	54%	5.5%	3.40%
	Mine-exposed	EV_DC3	2020	1	5,304	1,850	34	1,000	816	3,202	35%	0.64%	19%	15%	60%
		EV_DCOUT	2020	1	3,940	1,100	480	80	540	1,980	28%	12%	2.0%	14%	50%
		RG_HARM5	2014	1	17,400	16,400	8,560	7,000	840	900	94%	49%	40%	4.8%	5.2%
			2015	1	13,280	12,840	6,740	4,940	1,160	320	97%	51%	37%	8.7%	2.4%
			2020	1	18,240	16,500	7,340	7,840	1,320	1,560	90%	40%	43%	7.2%	8.6%
		RG_HACKUS	2012	1	25,500	21,680	7,420	13,760	500	3,400	85%	29%	54%	2.0%	13%
			2015	1	15,540	13,140	5,600	5,780	1,760	1,940	85%	36%	37%	11%	12%
			2016	1	18,320	15,680	8,480	6,360	840	1,900	86%	46%	35%	4.6%	10%
			2018	1	35,640	31,020	8,840	20,820	1,360	4,180	87%	25%	58%	3.8%	12%
			2019	1	57,360	49,420	28,500	14,640	6,280	6,680	86%	50%	26%	11%	12%
			2020	1	11,100	9,380	5,000	3,800	580	1,360	85%	45%	34%	5.2%	12%
Grave Creek	Reference	RG_GRUHA	2012	1	10,100	9,675	3,725	5,200	750	400	96%	37%	51%	7.4%	4.0%
			2013	1	8,960	8,860	2,680	6,020	160	80	99%	30%	67%	1.8%	0.89%
				1	36,940	36,100	9,280	25,920	900	820	98%	25%	70%	2.4%	2.2%
				2	11,880	11,820	2,280	9,400	140	60	99%	19%	79%	1.2%	0.51%
				3	18,160	17,940	4,700	12,920	320	180	99%	26%	71%	1.8%	1.0%
			2014	1	17,680	17,480	7,740	9,280	460	180	99%	44%	52%	2.6%	1.0%
			2015	1	4,875	4,662	2,212	1,862	588	150	96%	45%	38%	12%	3.1%
	Mine-exposed	RG_HACKDS	2012	1	35,000	15,800	8,300	6,400	1,100	18,100	45%	24%	18%	3.1%	52%
			2013	1	12,180	9,700	4,500	4,320	880	1,900	80%	37%	35%	7.2%	16%
			2014	1	26,100	17,620	5,940	7,300	4,380	6,300	68%	23%	28%	17%	24%
				1	17,980	13,300	8,460	3,740	1,100	3,940	74%	47%	21%	6.1%	22%
				2	17,640	13,120	7,920	3,140	2,060	3,920	74%	45%	18%	12%	22%
				3	19,540	15,860	8,000	4,160	3,700	3,100	81%	41%	21%	19%	16%
			2015	1	14,020	8,660	6,200	1,960	500	4,960	62%	44%	14%	3.6%	35%
				1	10,160	5,120	2,960	1,140	1,020	4,080	50%	29%	11%	10%	40%
			2016	1	7,280	3,280	2,020	800	460	3,280	45%	28%	11%	6.3%	45%
			2017	1	25,380	12,240	7,080	3,660	1,500	8,400	48%	28%	14%	5.9%	33%
			2018	1	29,500	16,480	13,060	2,160	1,260	12,080	56%	44%	7.3%	4.3%	41%
				2	18,080	11,820	9,000	1,780	1,040	5,820	65%	50%	10%	5.8%	32%
				3	16,560	5,540	4,740	480	320	10,100	33%	29%	2.9%	1.9%	61%
				4	21,040	12,340	9,020	2,340	980	7,420	59%	43%	11%	4.7%	35%
				5	14,340	8,820	4,620	2,580	1,620	4,180	62%	32%	18%	11%	29%
			2019	1	24,180	18,600	11,240	5,160	2,200	4,840	77%	46%	21%	9.1%	20%
				2	45,800	16,680	11,840	3,300	1,540	25,380	36%	26%	7.2%	3.4%	55%
				3	29,940	16,340	11,180	3,040	2,120	10,940	55%	37%	10%	7.1%	37%
				4	47,280	21,380	14,640	4,740	2,000	17,040	45%	31%	10%	4.2%	36%
				5	15,460	9,340	5,200	2,500	1,640	4,000	60%	34%	16%	11%	26%
			2020	1	31,540	12,180	8,280	2,200	1,700	18,580	39%	26%	7.0%	5.4%	59%
				2	52,920	19,260	11,940	2,600	4,720	31,920	36%	23%	4.9%	8.9%	60%
				3	32,180	10,480	6,900	2,100	1,480	20,340	33%	21%	6.5%	4.6%	63%
				4	22,020	13,020	9,640	1,540	1,840	7,360	59%	44%	7.0%	8.4%	33%
				5	39,920	13,880	10,180	2,400	1,300	23,620	35%	26%	6.0%	3.3%	59%
		RG_GRCK	2012	1	11,133	9,033	5,900	1,800	1,333	1,967	81%	53%	16%	12%	18%
			2015	1	7,740	6,760	3,420	1,800	1,540	820	87%	44%	23%	20%	11%
		RG_GRDS	2012	1	22,500	13,750	6,450	5,800	1,500	7,450	61%	29%	26%	6.7%	33%
			2013	1	6,260	5,120	500	3,740	880	880	82%	8.0%	60%	14%	14%
			2014	1	22,340	19,140	5,220	9,620	4,300	2,560	86%	23%	43%	19%	11%
				1	7,420	5,540	1,600	3,080	860	1,380	75%	22%	42%	12%	19%
			2015	1	8,400	6,360	2,540	2,160	1,660	1,760	76%	30%	26%	20%	21%
			2018	1	28,060	22,520	9,100	11,000	2,420	4,780	80%	32%	39%	8.6%	17%
			2019	1	21,260	14,440	8,100	4,680	1,660	5,480	68%	38%	22%	7.8%	26%
			2020	1	30,220	24,100	9,160	12,640	2,300	4,940	80%	30%	42%	7.6%	16%

[Shaded] Result is less than the corresponding reference area normal range calculated from data collected between 2012 and 2019 as part of the RAEMP; Minnow 2020).

Notes: ID = identifier; No. = number; min = minute; EPT = combined Ephemeroptera, Plecoptera, and Trichoptera; % = percent; RAEMP = Regional Aquatic Effects Monitoring Program.

Table A.6: Temporal Changes in Ephemeropteran, Plectopteran, and Trichopteran (EPT) Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.468	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	1.000	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.157	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.207	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.045	base year	-1.2	-0.15	-2.1	-3.8	-0.62	-1.0	0.014	-0.39	AB	AB	A	AB	B	AB	AB	A	A
		RG_GRCK	1.000	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.220	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.7: Temporal Changes in Ephemeropteran Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.479	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	1.000	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.178	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.553	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.060	base year	-1.4	-0.23	-1.5	-3.2	-0.36	-0.24	0.48	0.24	AB	AB	AB	AB	B	AB	AB	A	A
		RG_GRCK	0.992	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.004	base year	**-5.8**	-1.8	-2.1	-	-	0.78	0.52	0.80	A	B	A	AB	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.8: **Temporal Changes in Plecopteran Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020**

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.761	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.999	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.307	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.061	base year	1.7	1.2	-2.1	-	-	-	-	-	AB	A	AB	B	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.103	ns	ns	ns	ns	ns	ns	ns	ns	ns	A	A	A	A	A	A	A	A	A
		RG_GRCK	1.000	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.265	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.9: Temporal Changes in Trichopteran Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.357	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	1.000	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.147	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.880	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.319	ns	ns	ns	ns	ns	ns	ns	ns	ns	A	A	A	A	A	A	A	A	A
		RG_GRCK	1.000	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.956	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- [grey] P-value <0.1.
- [light green] >2 SD increase.
- [green] >3 SD increase.
- [medium green] >4 SD increase.
- [dark green] >5 SD increase.
- [light blue] >2 SD decrease.
- [blue] >3 SD decrease.
- [medium blue] >4 SD decrease.
- [dark blue] >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- [bright green] Significantly greater than historical years.
- [bright blue] Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.10: Temporal Changes in Dipteran Abundance for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.101	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.760	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.756	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.949	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.071	base year	-3.3	-2.2	-2.1	-2.5	-1.1	-1.3	-0.91	0.023	AB	AB	B	AB	AB	AB	AB	AB	A
		RG_GRCK	0.989	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.417	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.11: Temporal Changes in Proportions of Ephemeroptera, Plectoptera, and Trichoptera for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	1.000	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	1.000	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	1.000	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	1.000	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.003	base year	3.2	2.7	1.0	-0.0083	0.29	0.92	0.90	-0.46	AB	A	A	AB	AB	AB	AB	AB	B
		RG_GRCK	1.000	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.859	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.12: Temporal Changes in Proportions of Ephemeroptera for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Harmer Creek	Reference	RG_HARM6_25	1.000	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.999	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.588	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.463	ns	ns	ns	ns	-	-	-	-	-	A	A	A	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.395	ns	ns	ns	ns	ns	ns	ns	ns	ns	A	A	A	A	A	A	A	A	A
		RG_GRCK	1.000	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.007	base year	**-5.1**	-0.97	0.21	-	-	0.49	1.1	0.22	A	B	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[\text{Mean}_{\text{given year}} - \text{Mean}_{\text{base year}}]/\text{SD}_{\text{base year}}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.13: **Temporal Changes in Proportions of Plecoptera for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020**

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.957	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.989	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.001	base year	-	-	-3.8	-4.3	-	1.0	**-6.4**	**-4.4**	AB	-	-	BC	BC	-	A	C	C
Grave Creek	Reference	RG_GRUHA	<0.001	base year	**4.6**	0.23	-3.0	-	-	-	-	-	B	A	B	B	-	-	-	-	-
	Mine-exposed	RG_HACKDS	<0.001	base year	3.9	0.83	-1.3	-1.6	-0.87	-1.9	-1.2	-2.7	ABC	A	AB	BC	BC	BC	C	BC	C
		RG_GRCK	0.962	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	<0.001	base year	**7.7**	3.7	-0.014	-	-	3.0	-0.85	3.6	BC	A	B	BC	-	-	BC	C	AB

P-value <0.1.
>2 SD increase.
>3 SD increase.
>4 SD increase.
>5 SD increase.
>2 SD decrease.
>3 SD decrease.
>4 SD decrease.
>5 SD decrease.
bold Significant increase or decrease from base year.
Significantly greater than historical years.
Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.14: Temporal Changes in Proportions of Trichoptera for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.967	-	ns	ns	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.994	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	0.297	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.049	base year	-2.9	-2.1	0.97	-	-	-	-	-	AB	B	AB	A	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.172	ns	ns	ns	ns	ns	ns	ns	ns	ns	A	A	A	A	A	A	A	A	A
		RG_GRCK	0.998	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.825	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".

Table A.15: Temporal Changes in Proportions of Diptera for Reference and Mine-exposed Areas in the Harmer Creek and Grave Creek Population Areas, September 2012 to 2020

Corresponding Westslope Cutthroat Trout Population	Status	Area ID	Year P-value [a]	Q1. Is there a positive or negative change since the base year of monitoring? Magnitude of Difference (MOD) [b] and Significance (bolded) from Base Year [c]									Q2. Do the September means differ among years? [c]								
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2012	2013	2014	2015	2016	2017	2018	2019	2020
Harmer Creek	Reference	RG_HARM6_25	0.066	-	base year	**4.7**	-	-	-	-	-	-	-	B	A	-	-	-	-	-	-
	Mine-exposed	EV_DC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EV_DCOUT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		RG_HARM5	0.286	-	-	ns	ns	-	-	-	-	ns	-	-	A	A	-	-	-	-	A
		RG_HACKUS	1.000	ns	-	-	ns	ns	-	ns	ns	ns	A	-	-	A	A	-	A	A	A
Grave Creek	Reference	RG_GRUHA	0.051	base year	**-3.9**	-3.8	-0.71	-	-	-	-	-	A	B	AB	AB	-	-	-	-	-
	Mine-exposed	RG_HACKDS	0.018	base year	-3.4	-2.6	-0.89	-0.39	-1.2	-0.84	-1.3	0.10	AB	B	B	AB	AB	AB	AB	AB	A
		RG_GRCK	0.980	ns	-	-	ns	-	-	-	-	-	A	-	-	A	-	-	-	-	-
		RG_GRDS	0.639	ns	ns	ns	ns	-	-	ns	ns	ns	A	A	A	A	-	-	A	A	A

- P-value <0.1.
- >2 SD increase.
- >3 SD increase.
- >4 SD increase.
- >5 SD increase.
- >2 SD decrease.
- >3 SD decrease.
- >4 SD decrease.
- >5 SD decrease.
- **bold** Significant increase or decrease from base year.
- Significantly greater than historical years.
- Significantly less than historical years.

Notes: ID = identifier; - = insufficient data for comparison; ns = not significant; < = less than; > = greater than; SD = standard deviation; ANOVA = Analysis of Variance.

[a] *Year* p-value from an ANOVA.

[b] Magnitude of Difference (MOD) = $[Mean_{given\ year} - Mean_{base\ year}]/SD_{base\ year}$.

[c] Significance among years determined using all pairwise comparisons using Tukey's honestly significant differences method. Years that share a letter are not significantly different. Letters assigned such that the mean with highest magnitude is assigned "A".