# Aquatic Resources 2016 Baseline Study Addendum Report

Stibnite Gold Project
Midas Gold Idaho, Inc.


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# SECTION 1 POPULATION ESTIMATES FOR STUDY REACHES

Midas Gold Idaho Inc. (Midas Gold) has been conducting environmental baseline studies in support of its Plan of Restoration and Operations (PRO) in the Payette National Forest (PAF) and Boise National Forest of Idaho. The aquatic resources baseline studies include an extensive set of surveys of aquatic habitat, and of the fish and invertebrate populations within that habitat. For fish, which are the focus of this addendum, multiple years of diver-based snorkel surveys have been conducted to establish the presence or absence of four key salmonid species (Chinook salmon, steelhead trout, bull trout, and westslope cutthroat trout), and to provide a basis for tracking trends in fish abundance over time. These snorkel surveys have been conducted at many stream and river sites covering the salmonid-bearing waters within the aquatics resources study area for the project, and are described in the main aquatic resources baseline report.

Snorkel surveys are not typically considered a preferred method for quantifying the number of fish that are present in a stream. Divers may have difficulty counting fish, or identifying the fish to species when fish numbers are high; where complex habitat offers hiding places; and/or when fish flee in response to seeing the divers or sensing their approach. Fish are not handled in snorkel surveys, so quantitative measurements of fish lengths and weights are not collected, but subjective estimates of fish length are often made.

Three salmonid species, Chinook, steelhead trout and bull trout, are listed under the federal Endangered Species Act, so regulatory authority to use more traditional fish sampling methods, electrofishing and mark-recapture, has been difficult to obtain due to concerns about potential impacts to fish from these methods. However, in 2015, the PAF obtained regulatory approval for a limited program of electrofishing and mark-recapture, which was conducted at nine established fish survey sites. The sites were separated into five strata to cover a wide range of habitat types present in the aquatic resources study area. The sampling protocol, covered in more detail below, involved simultaneously conducting snorkel surveys, four-pass electrofishing depletion surveys, and a mark-recapture study, thus allowing the results of all three methods to be compared to one another.

To support the PAF’s environmental review and permitting of Midas Gold’s proposed mining operations, an Aquatic Resources Baseline Report (Baseline Report) (MWH 2017) was submitted to the Forest Service for their review. PAF responded, in part, by requesting that the Baseline Report be expanded to include the results of the electrofishing/mark-recapture surveys. Specifically, the PAF requested that Midas Gold: (1) use the quantitative survey data to calculate estimates of the fish populations in each sampled site; (2) compare the resulting electrofishing and mark-recapture estimates to determine the amount of sampling bias, defined here as the amount the electrofishing estimates differed from the mark-recapture estimates; and (3) to review the quantitative data and resulting population estimates to determine if they are appropriate to use as correction factors to adjust the snorkel survey data so that they provide more accurate estimates of fish population size.

Expanding the electrofishing and mark-recapture field data into fish population estimates at each site, is covered under this Section 1. Determining the bias in the electrofishing estimates, is covered in Section 2, below. Determining the suitability of the quantitative surveys to develop correction factors is indirectly covered in both Parts 1 and 2 in the discussions on the quality and accuracy of the quantitative data and analytical results. In addition, Section 2 ends with a summary directly addressing Task 3.

## 1.1 Methods

During summer 2015, MWH (MWH), and the PAF conducted fish sampling at nine sites in the aquatics resources study area (**Figure 1**). The sample sites included three in the East Fork South Fork Salmon River (EFSFSR) (MWH-026, MWH-025, and MWH-011), three Meadow Creek sites (MWH-016, MWH-034, MWH-014), one in Cinnabar Creek (MWH-19), and one in Sugar Creek (MWH-018). The sampling techniques included: (1) four-pass depletion electrofishing (electrofishing), (2) single census mark-recapture sampling (mark-recapture), and (3) snorkel surveys. The first two techniques are quantitative, and can be used to calculate an estimate of the population sizes of spatially defined sample units in streams and rivers. Depletion methods use the number of captured fish over the four sampling runs to estimate population size. Mark-recapture equations use the number of marked fish that are recaptured as a proportion of all captured fish to estimate population size.

Details on the sampling methods used are provided in the main body of the Baseline Report (MWH 2017). In summary:

- Block nets were installed at both ends of approximately 100-meter long sample reaches.
- Some fish from the blocked reach were captured using electrofishing gear.
- After being identified to species and measured, captured fish were given either a dorsal- or a caudal-fin clip and returned to the sample reach.
- Approximately 24 hours later, divers censused each reach using snorkel gear, with both marked and unmarked fish enumerated, and fish size estimated.
- Dive surveys were immediately followed with four-pass electrofishing. The number of both marked and unmarked fish was recorded on each pass. The fish from each pass were retained until the completion of all four passes.
- Block nets were removed and all fish were released back into the stream.

Dive surveys were not needed to calculate fish population numbers. The dive surveys were conducted so that their results could be compared to results from electrofishing and mark-recapture studies.


**Figure 1**
**Study Sites**

Projection: Idaho TM NAD83
Aerial Imagery: NRCS NAIP 2015
Biomonitoring Locs: Forest Service
Other Data: State of Idaho Geospatial Gateway (INSIDE Idaho); Payette National Forest
Map Prepared: June, 2017

### 1.1.1 Electrofishing Methods

Electrofishing on the day following fish marking always included four passes, with an attempt to approximate the same number of seconds of electrical field generation in each pass. Fish in a wide range of sizes were captured, and westslope cutthroat trout was the dominant species, with bull trout, redband trout (a subspecies of rainbow trout) and Chinook salmon present at some sites. Except as noted in the results, all captured fish were grouped together for purposes of estimating population size regardless of fish size or species.

The number of fish captured on each electrofishing pass was used to calculate the population-level estimate and standard error for that estimate for each site. The population estimates were calculated from a U.S. Fish and Wildlife Service modification of the Zippin (1958) equations (as cited in Armour et al. 1983). These equations, which are presented in **Attachment 1**, have two key assumptions. The first is that the population being sampled is closed, meaning that fish cannot move into, or out of, the population being sampled. This assumption was maintained in all cases because the population being sampled were fish trapped between block nets at either end of each sampling reach, nets which remained in place from the beginning to the end of the four passes of electrofishing. The second assumption is that fish have an equal probability of capture on each electrofishing pass. This assumption is rarely met for two reasons. First, the vulnerability to electrofishing increases with fish size due to the larger surface area subject to electrical current. In practice, large fish are often preferentially captured in the earlier passes, and the remaining smaller fish, which are more difficult to capture, have a lower probability of capture in the latter passes. Second, fish exposed to electrofishing frequently exhibit flight behaviors and may travel into complex structures like large woody debris jams, or small spaces between or under boulders and cobbles. Once in those locations fish can be difficult to capture on subsequent electrofishing passes. An indicator that capture probability is varying across passes is the failure to observe a clear decline in number of fish captured with each subsequent pass. In such cases, and particularly when the number of fish caught on the third and fourth passes is similar to capture numbers of earlier passes, the Zippin equations yield population estimates with high standard error, that is, estimates with low statistical confidence.

### 1.1.2 Mark-Recapture Methods

Only salmonids were marked. Westslope cutthroat trout were the most frequently marked species, with lesser numbers of Chinook salmon, redband trout, and bull trout. Fish sizes varied but were generally between 100 and 220 millimeters (mm) long. The total number of fish captured across the four electrofishing passes were used to estimate fish population sizes. Mark-recapture estimates of population size and standard error were calculated using the Chapman estimator (https://en.wikipedia.org/wiki/Mark_and_recapture). The equations are presented in **Attachment 1**. This modification of the standard mark-recapture equations (Lincoln-Petersen estimator) exhibits less statistical bias at low sample sizes of recaptured fish. All of the study sites had low numbers of both marked and recaptured fish.

Mark-recapture equations assume a closed population. This assumption was maintained for seven of the nine sampled sites. However, in two sites one of the two block nets partially failed (i.e., was overtopped or pulled away from the stream bank) in the period between the release of marked fish and the electrofishing effort to recapture those marked fish. In MWH- 011 on the EFSFSR, all but one of the marked fish was recaptured through electrofishing, and the last marked fish was found trapped in the downstream block net, suggesting very little population movement out of this sample reach. In the second site with a failed block net, MWH-025 on the EFSFSR, there was a low number of marked fish captured, but whether this was due to movement of fish past the block net and out of the sample reach is unknown.

## 1.2 Results

This section provides the results from the electrofishing study, the mark-recapture study, and the size class analysis.

### 1.2.1 Electrofishing

The total number of fish captured during the four-pass electrofishing runs varied considerably between sites, with numbers ranging between 52 (MWH-025) and 2 (MWH-047) (**Table 1-1**). All but two sites (MWH-016, MWH-011) yielded the highest number of fish captures on the first pass, but depletion in the number of fish captured in subsequent passes was inconsistent. For four sites the number of fish collected on the third pass exceeded those collected on the second pass (MWH-014, MWH-018, MWH-025, MWH-047). And for three sites the number collected on the fourth pass exceeded the numbers in the second or third pass or both (MWH-016, MWH-019, MWH-026). The inconsistent depletion across the four passes indicates that capture efficiency was not constant for each electrofishing pass.

The pattern of inconsistent depletion strongly affected the results derived from the Armour et al. (1983) equations in that population estimates were generally very similar to the total number of fish captured. This similarity led to small standard error values (less than 10 percent of population estimate) for most sites. All sites except for MWH-016 and MWH-025 had electrofishing population estimates of 26 fish or less, with most sites in the range of 13 to 26 fish in the 100-meter reach (**Table 1-1**). MWH-014 and MWH-047 had the lowest estimates of population (8 and 2 fish, respectively). For MWH-016, the number of fish captured on the fourth pass equaled or exceeded the number captured on the first and third passes. Given the absence of depletion across passes, the population estimate for MWH-016 cannot be estimated with any accuracy, as evidenced by a standard error that was more than 300 percent of the population estimate.

**Table 1-1. Population Estimates for Four-Pass Electrofishing**

| MWH Site ID | Stream | Stratum | Total Fish in 4 Passes | Total Fish in Pass 1 | Total Fish in Pass 2 | Total Fish in Pass 3 | Total Fish in Pass 4 | Population Estimate of Reach | Standard Error of Population Estimate |
|---|---|---|---|---|---|---|---|---|---|
| 016 | Meadow Creek | 1 | 23 | 6 | 7 | 4 | 6 | 124 | 409.94 |
| 019 | Cinnabar Creek | 1 | 25 | 17 | 3 | 1 | 4 | 26 | 1.67 |
| 026 | EFSFSR | 1 | 24 | 17 | 3 | 1 | 3 | 25 | 1.13 |
| 034 | Meadow Creek | 1 | 12 | 6 | 4 | 1 | 1 | 13 | 1.51 |
| 014 | Meadow Creek | 2 | 8 | 5 | 1 | 2 | 0 | 8 | 0.76 |
| 018 | Sugar Creek | 2 | 21 | 12 | 3 | 4 | 2 | 23 | 2.50 |
| 025 | EFSFSR | 3 | 52 | 26 | 7 | 14 | 5 | 62 | 7.32 |
| 011 | EFSFSR | 4 | 13 | 4 | 5 | 4 | 0 | 16 | 4.35 |
| 047 | Meadow Creek | 5 | 2 | 1 | 0 | 1 | 0 | 2 | 1.70 |

Key:
EFSFSR = East Fork of the South Fork of the Salmon River

### 1.2.2 Mark-Recapture

Sample sizes of fish that were captured and marked varied considerably from a high of 38 fish at MWH-025 to a low of 8 fish at MWH-018, MWH-011, and MWH-047 (**Table 1-2**). As noted, most marked fish were westslope cutthroat trout between 100 and 220 mm long. The number of marked fish that were subsequently recaptured generally followed a bimodal distribution with two of the nine sites having more than 20 recaptures, and all but one of the remaining having less than eight fish recaptured (**Table 1-2**).

The population estimates derived by mark-recapture spanned a greater range than the electrofishing estimates, with a high of 97 fish and a low of 8 fish in the 100 meter reaches (**Table 1-2).** Three groupings of sites were evident: two had much higher population estimates (MWH-025 and MWH-018 with 97 and 65 fish, respectively). Four had a relatively tight cluster of 26 to 35 fish estimated (MWH-016, MWH-019, MWH-026, MWH-034). And three sites had low population estimates (MWH-014, MWH-011, and MWH-047 with 14, 15, and 8 fish, respectively). Standard errors were generally 20 percent or less of the population estimates (**Table 1-2**), a result suggesting those estimates were statistically robust.

When the number of initially marked and released fish represents 50 percent or more of the population of fish available to be marked the statistical bias of the mark-recapture method is considered low (Jensen 1992). The number of initially marked fish represented 100 percent to 12.3 percent of the mark-recapture estimated population size, with values for all sites except MWH-016, MWH-018, and MWH-025 at 44 percent or more. This suggests the population estimates using the mark-recapture data are statistically robust. This conclusion is tempered somewhat for MWH-018 and MWH-047, where the number of recaptures was very low, which can lead to statistical imprecision in the mark-recapture methodology.

**Table 1-2. Population Estimates for Mark-Recapture**

| MWH Site ID | Stream | Stratum | Total Number of Fish Marked | Number of Marked Fish Recaptured | Population Estimate of Reach | Standard Error of Population Estimate |
|---|---|---|---|---|---|---|
| 016 | Meadow Creek | 1 | 19 | 14 | 31 | 2.45 |
| 019 | Cinnabar Creek | 1 | 10 | 7 | 35 | 5.18 |
| 026 | EFSFSR | 1 | 23 | 21 | 26 | 0.57 |
| 034 | Meadow Creek | 1 | 12 | 5 | 27 | 5.73 |
| 014 | Meadow Creek | 2 | 9 | 5 | 14 | 2.07 |
| 018 | Sugar Creek | 2 | 8 | 2 | 65 | 25.04 |
| 025 | EFSFSR | 3 | 38 | 20 | 97 | 11.08 |
| 011 | EFSFSR | 4 | 8 | 7 | 15 | 1.15 |
| 047 | Meadow Creek | 5 | 8 | 2 | 8 | 0.00 |

Note: The numbers reported here are only for fish that were subsequently fin-clipped and released back into the stream. The initial effort to obtain fish for marking also led to the capture of young-of-the-year fish that were too small for fin clips, and non-salmonid species not included in the marking program
Key:
EFSFSR = East Fork of the South Fork of the Salmon River

### 1.2.3 Size Class Analysis for Site MWH-025

The population estimates described above are for all salmonid species and sizes combined. Except for MWH-025, the total number of fish captured through the four-pass electrofishing runs was too small to do a separate analysis to evaluate population estimates for individual species or for different size ranges. However, an analysis for MWH-025 was conducted in which the captured fish were divided into two size ranges: less than or equal to 100 mm, and greater than or equal to 100 mm. All fish captured at MWH-025 were westslope cutthroat trout, therefore no test for different species was possible. The Zippin analysis of these datasets yielded estimates of 28 fish that were less than or equal to 100 mm, and 32 fish greater than 100 mm. The sum of these two size classes, 60 fish, is 2 fish less than the Zippin estimate of population size when all size classes were combined. The mark-recapture estimates were 56 and 49 fish for the less than or equal to 100 mm size class, and greater than 100 mm size class, respectively. The sum, 105 fish, is 8 fish more than the mark-recapture estimate of population size when all size classes were combined. Both the electrofishing- and mark-recapture-based estimates indicated that the number of fish in the two size classes were similar.

## 1.3 Discussion

In comparing the population estimates between the electrofishing and mark-recapture results, two patterns are obvious. First, each method demonstrated that the number of fish in the 100-meter sample sites varied to a large degree. Sites with the highest estimated population levels (e.g., MWH-025) had up to 10 times more fish than in reaches with the lowest population levels (e.g., MWH-047). Second, comparing across sites, mark-recapture efforts yielded higher estimates of population size than those of nearly every electrofishing estimate. Of the two exceptions, MWH-016 had an unreliable electrofishing estimate of population size, as noted above. MWH-011 had electrofishing and mark-recapture population estimates that were different by only one fish (i.e., population estimate of 16 versus 15).

The observation that mark-recapture leads to higher population estimates than most four-pass electrofishing has been commonly observed in the literature (e.g., Peterson et al. 2004), and is believed to be due to violation of the assumption of equal capture probability across passes. Whether due to smaller size, or avoidance, fish still present in the sample reaches in late passes are less likely to be captured than fish in earlier passes. Computationally, this causes the Zippin equations to overestimate sampling efficiency, and by extension, to underestimate population size.

Despite some issues with the depletion across sampling runs, and low sample sizes of marked/recaptured fish, field crews reported that they felt that they used good field techniques, and all work was implemented by the same trained crews using the same methods. Rather than technique, part of the poor electrofishing efficiency is likely a consequence of site specific factors like low conductivity water (electrofishing efficiency decreases at lower water conductivity), and complex habitat such as large woody debris jams that offer shelters to fish which are difficult to sample with electrofishing gear. In addition, snorkel surveys were conducted prior to, and on the same day as, electrofishing surveys. These diving surveys may have affected capture rates during electrofishing surveys. Factors affecting electrofishing efficiency are discussed further below in **Section 2**.

Although additional quantitative estimates of fish populations in these reaches would be of interest, those presented here likely represent fair to good estimates of the true population size for most reaches sampled. The population estimates based on the mark-recapture methodology are likely superior to those based on four-pass depletion electrofishing in most cases.

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# SECTION 2 CALCULATIONS OF SAMPLING BIAS

As discussed in **Section 1**, population estimates for study sites were derived using both four-pass electrofishing, and mark-recapture methods. Also noted was the documented tendency for electrofishing-based methods to overestimate capture efficiency, and therefore to underestimate population size. Meyer and High (2011) outlined methods to compare electrofishing and mark-recapture population estimates to estimate sampling "bias," defined as the variance in population estimates derived from electrofishing compared to those from mark-recapture. Implicit in this analysis is the assumption that the mark-recapture estimates are themselves unbiased, that is, the population estimates derived using this method are accurate, and not subject to a systematic error.

The methods used in Meyer and High (2011) involved two estimates of electrofishing bias. The first method compared the number of marked fish estimated from the electrofishing results with the actual number of marked fish. The estimated value uses the standard Zippin equations, but inputs to those equations are the number of marked fish captured in each electrofishing pass rather than the total number of fish. Thus, the Zippin population estimate effectively becomes an estimate of the population of marked fish, a value that is known with certainty (i.e., based on the field records of the number of fish that were captured-marked-released in each reach). The specific equation used is:

> Bias Estimate 1 = 1 – (Electrofishing Estimate of the Number of Marked Fish / Actual Number of Marked Fish)

A value of 0 means the estimated number of marked fish is exactly equal to the actual number marked (i.e., bias = 0). A value of 0.25 means that the electrofishing estimate was 25 percent less than the actual number of marked fish. And a value of -0.25 means the electrofishing estimate was 25 percent higher than actual.

The second bias estimate of Meyer and High (2011) directly compares the population estimate for all fish derived from the four-pass electrofishing to that from mark-recapture. The equation used is:

> Bias Estimate 2 = 1 – (Population Estimate Electrofishing / Population Estimate Mark-Recapture)

Interpretation of values from this equation are the same as for Bias Estimate 1: 0 means the two population estimates are the same, 0.25 means the electrofishing estimate is 25 percent less than the mark-recapture estimate, and -0.25 means it is 25 percent higher.

For Bias Estimate 1, the raw data on fish removals during each electrofishing pass at each Site were examined to identify the number of marked fish captured. These values were then processed through the Armour et al. (1983) modification of the Zippin equations to generate population estimates for marked fish at each reach (i.e., same procedure as in **Section 1**, but using only records for marked fish). These estimates were divided by the number of fish marked at each reach in accordance with the equation above.

For Bias Estimate 2, the population estimates derived for each reach using four-pass electrofishing and mark-recapture as reported in **Section 1** of this addendum were used in accordance with the equation above.

## 2.1 Results Bias Estimate 1

Excluding MWH-016, values for Bias Estimate 1 ranged from -0.27 to 0.75 (**Table 2-1**). All sites except MWH-011 had positive values, meaning that the electrofishing estimate of the number of marked fish was less than the number of fish marked. Four sites, MWH-019, MWH-026, MWH-025, and MWH-011, had electrofishing estimates of marked fish that were within 27 percent of the actual number (i.e., Bias 1 values of -0.27 to 0.27). For the remaining sites, bias was 44 percent or more. Most sites had a weak pattern of depletion across the four passes, or small samples sizes for the number of marked fish that were recaptured, or both. The result is that the Zippin equation-based estimate of the population of marked fish is the same as the number of marked fish that were recaptured for most sites.

For MWH-016, the number of marked fish did not decrease across the four electrofishing passes (values of 2, 3, 5, and 4 for the four passes, respectively), a result similar to that for all captured fish, as discussed in **Section 1**. The result is that the Zippin equations produce unreliable or even irrational results (e.g., estimate for marked fish of -23) for this site. Bias estimates for MWH-016 are therefore not considered further.

## 2.2 Results Bias Estimate 2

The bias values calculated for Bias Estimate 2 were similar to those from Bias Estimate 1, ranging from -0.08 to 0.69 (**Table 2-1**). All sites except MWH-011 had positive bias values, meaning that the electrofishing estimate of the total number of fish in each reach was less than the mark-recapture estimate for that reach. Only three sites, MWH-019, MWH-026, and MWH-011, had electrofishing estimates of fish population size that were within 25 percent of the estimate calculated using mark-recapture. For the remaining sites, bias was 36 percent or more.

**Table 2-1. Bias Estimates for Electrofishing Results**

| MWH Site ID | Stream | Stratum | Total Marked Fish | Marked Fish Recaptured in 4 Passes | Estimated Number of Marked Fish Using Electrofishing | Bias Estimate 1 | Population Estimate of Reach: Electrofishing | Population Estimate of Reach: Mark-Recapture | Bias Estimate 2 |
|---|---|---|---|---|---|---|---|---|---|
| 016 | Meadow Creek | 1 | 19 | 14 | -23 | 2.21 | 124 | 31 | -3.01 |
| 019 | Cinnabar | 1 | 10 | 7 | 7 | 0.26 | 26 | 35 | 0.24 |
| 026 | EFSFSR | 1 | 23 | 21 | 21 | 0.07 | 25 | 26 | 0.06 |
| 034 | Meadow Creek | 1 | 12 | 5 | 5 | 0.58 | 13 | 27 | 0.53 |
| 014 | Meadow Creek | 2 | 9 | 5 | 5 | 0.44 | 8 | 14 | 0.41 |
| 018 | Sugar Creek | 2 | 8 | 2 | 2 | 0.75 | 23 | 65 | 0.65 |
| 025 | EFSFSR | 3 | 38 | 20 | 29 | 0.23 | 62 | 97 | 0.36 |
| 011 | EFSFSR | 4 | 8 | 7 | 10 | -0.27 | 16 | 15 | -0.08 |
| 047 | Meadow Creek | 5 | 8 | 2 | 2 | 0.69 | 2 | 8 | 0.69 |

Notes:
MWH-016 had skewed sampling across passes, resulting in unreliable estimates using Zippin equations
Values have been rounded to the nearest whole number. Before rounding, all sites showed at least small differences in the estimated number of marked fish and the number actually recaptured.
Key:
EFSFSR = East Fork of the South Fork of the Salmon River

## 2.3 Discussion

Both methods to estimate bias contained in Meyer and High (2011) lead to the conclusion that the electrofishing data result in underestimates of fish population size for the survey sites. This is a commonly reported result in the scientific literature. For example, Peterson et al. (2004) sampled 43 stream reaches in Idaho and Montana known or thought to support bull trout. Their study sites included Rocky Mountain streams with cold, low conductivity water, and complex habitat reaches, conditions very similar to those of the sites reviewed for this baseline study. They reported an average bias estimate of 88 percent, meaning electrofishing underestimated the population size calculated using mark-recapture methods by 88 percent. This bias level is higher than that calculated for eight of the nine stream sites sampled in this baseline study. Meyer and High (2011) worked in 23 streams in southern Idaho, again including cold, low conductivity locations with high habitat complexity. They reported average bias estimates of 17 to 27 percent, with values for individual streams often much higher. As noted in the results, several sites evaluated in this Addendum Report had bias estimates of approximately 27 percent or less, similar to the averages reported by Meyer and High (2011). Given bias estimates in this baseline study were lower than or comparable to those reported in the literature, it seems clear that site conditions, rather than sampling technique, were responsible for those bias estimates. Further, the electrofishing estimates of population size for the Stibnite Gold study streams are likely reasonable estimates, comparable to or better than those expected in other electrofishing studies conducted under similar conditions.

The bias estimates showed much greater variation among sites than between the two methodologies employed to generate those estimates. Three lines of evidence indicate that this result is due to differences in localized habitat conditions that affected electrofishing efficiency:

- The Aquatic Resources Baseline Report (MWH 2017) provides an analysis of instream habitat (e.g., channel morphology, LWD loading, etc.) that documents that the sites varied widely in their habitat complexity. Large differences in habitat complexity would be expected to lead to differences in the ease or difficulty of capturing fish.
- The two bias estimates are really evaluation of two populations at each site: the population of marked fish, and the population of all fish. Because both populations were captured with a similar efficiency (i.e., had similar bias estimates) the implication is that environmental effects like habitat complexity were determining that efficiency, rather than variables like fish size or disturbance history that differed between the two populations.
- The proportion of marked fish that were captured at each site varied significantly, from 91 percent at MWH-026 to 25 percent at MWH-018 and MWH-047. Given the same equipment, methods, and crews were used for all electrofishing, it is unlikely this variance among sites was due to any change in how the surveys were done. Instead, differences in the ability to capture fish at the different sites seems likely.

Regardless of cause, differences in bias among sites seen in these datasets suggests that electrofishing as a potential future method to quantify fish in streams associated with the Stibnite Gold Project will be suitable for some sites (i.e., those with low bias), and not others. Where feasible and permitted by the resource agencies, electrofishing will be a preferred method for future sampling. Electrofishing has the advantage of being much quicker than mark-recapture for fish census work. Of necessity, mark-recapture studies require 2 days in the field at each site, one day to mark the fish and release them, and a second day to recapture the marked fish. Also, to maintain the assumption of a closed population, as required by mark-recapture studies, block nets or similar barriers must be erected and maintained across the two days of sampling. In practice, this can be difficult to do, as in the current study where two of nine sites had compromised fish barriers. Where electrofishing is used to collect fish for mark-recapture, the fish experience greater stress as they are exposed to electricity more times, and for those fish captured and marked, experience greater handling and physical impacts associated with the mark.

The analysis in this report assumed that the mark-recapture population methods are “unbiased,” in keeping with a similar assumption in other studies evaluating the efficacy of electrofishing methods (e.g., Peterson et al. 2005). In reality, mark-recapture methods can be subject to bias in at least three ways:

- When the assumption of a closed population is violated, as discussed above.
- When marked fish experience mortality or debilitating injury following marking, making them unavailable for recapture. The field methods used by the MWH/PAF field crew were very sensitive to avoiding injury to fish. Even so, some mortality was noted in fish during the marking effort. Mortality or debilitating injury in fish expressed after their release therefore cannot be automatically dismissed.
- Mark-recapture estimates are subject to much greater imprecision as the proportion of marked fish that are recaptured decreases (Meyer and High 2011). When fewer than 50 percent of marked fish are recaptured, the mark-recapture estimate assumes enough uncertainty, in the form of standard error or similar statistical measures, to constitute its own form of bias. In the current study, six of the nine sites had recapture proportions that exceeded 50 percent (MWH-016, MWH-019, MWH-026, MWH-014, MWH-025, MWH-011), while three did not.

Overall, the analysis of bias confirms that electrofishing generally underestimated the true population size of fish in each site. Depending on which of the methods were used to measure bias, either three or four of the survey sites had bias estimates of about 25 percent or less. Meyer and High (2011) proposed that a bias of about 25 percent is acceptable in electrofishing surveys for fish given the spatial and temporal variation in fish densities in streams, and the advantages that this faster sampling method (compared with mark-recapture) would allow in terms of number of sites sampled or frequency of sampling. For the remaining sites where bias was not at or below 25 percent, additional effort in any future electrofishing should be expended to try and increase the efficiency of such sampling. One obvious change would be to forego diver-based surveys immediately before electrofishing, as the former likely produced flight responses in many fish that may have made them less susceptible to capture in the electrofishing passes. Additional effort to increase the number of fish captured for marking, more electrofishing effort in complex structures (e.g., large woody debris jams), more seconds of electrofishing effort per pass, and use of salt blocks to temporarily increase water conductivity are other examples of changes that could improve future results.

The current study design was motivated, in part, by a desire to develop correction factors that could be applied to future, diver-based surveys. Diver surveys often report fewer fish than either electrofishing or mark-recapture studies. In a separate analysis of the diver surveys the proportion of marked fish that were observed was found to range from 0 to 39.1 percent, with an average of just 20.3 percent. By contrast, the proportion of marked fish recaptured by electrofishing averaged 58 percent, or nearly three fold greater. This documents the low efficiency of diver surveys compared to electrofishing, and by extension shows that uncorrected values from diver surveys are good for trends analysis or confirmation of species presence/absence, but are not themselves usually good estimates of fish abundance or density. On day two of the sampling at each site, fish counts were obtained with three methods: diver-based counts, electrofishing, and mark-recapture. Once an estimate of the true population is determined, whether through electrofishing or mark-recapture, this can be compared to the number of diver observed fish to develop the correction (i.e., correction factor = true population size/diver count). With the assumption that the bias in diver surveys remains more or less constant over time at each site, the correction factors could be applied to all past diving surveys to expand them to population level estimates.

Although the goal of developing correction factors remains valid, the existing datasets are limited and variable. Their use to set correction factors now would likely result in significant errors in the corrected snorkel survey estimates of fish numbers because of: (1) known bias in the electrofishing estimates of population size, (2) suspected bias in the mark-recapture estimates due to partial block net failure at two sites or low number of recaptures relative to the number of fish marked at other sites, and (3) lack of more than 1 year of data to confirm correction factors do not show strong, year to year variation. Another year of data could reduce these uncertainties, and would provide a basis for developing correction factors for the snorkel surveys that have lower levels of uncertainty. Additional data would also likely increase the sample size for less common fish species (e.g., bull trout), which could facilitate species specific analyses in the future.

# SECTION 3 REFERENCES

## 3.1 References Cited

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## 3.2 Abbreviations and Acronyms

| **Abbreviation/ Acronym** | **Definition** |
|---|---|
| EFSFSR | East Fork of the South Fork of the Salmon River |
| Midas Gold | Midas Gold Idaho Inc. |
| mm | millimeter |
| MWH | MWH now part of Stantec |
| PAF | Payette National Forest |

# SECTION 4 LIST OF PREPARERS

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# ATTACHMENT 1 EQUATIONS USED IN THE ADDENDUM TO THE MIDAS BASELINE AQUATIC REPORT

**Armour et al. (1983) Modification of Zippin (1957) for Electrofishing Depletion Estimates**

C = ((1*Pass 1) + (2*Pass 2) + (3*Pass 3) + (4*Pass4))

R = ((C-M)/M)

$P_{est}$ = ((a0*1) + (a1*R) + (a2*R2) + (a3R3) + (a4*R4))

$N_{est}$ = (M/(1-(1- $P_{est}$)t))

SE Numerator = $N_{est}$ *( $N_{est}$ -M)*M)

SE Denominator = (M2-( $N_{est}$ ($N_{est}$ -M)*((4* $P_{est}$)2))/(1- $P_{est}$))

SE = Square Root of (SE Numerator/SE Denominator)

*Where:*

C and R = Intermediate equation terms

Pass n (where n=1, 2, etc.) = Total number of fish captured on electrofishing pass n

M = Total number of fish captured in the four electrofishing passes

$P_{est}$ = Estimate of capture probability of an individual fish in each sample reach across the four passes

a0, a1, a2, a3, a4 = Equation constants (0.984082, -0.82045, 0.320498, -0.14113, 0, respectively)

$N_{est}$ = Estimated population size of fish in the sampled reach

t = Number of electrofishing passes

SE Numerator = Numerator portion of equation for standard error of $N_{est}$

SE Denominator = Denominator portion of equation for standard error of $N_{est}$

SE = Standard Error of Nest

**Chapman Modification for Mark-Recapture Estimates**

$N_{est}$ = (((K+1) * (n+1))/k+1))-1)

SE = Square Root of (((K+1) * (n + 1) * (K-k) * (n-k))/ ((k+1)2 * (k+2)))

*Where:*

$N_{est}$ = Estimated population size of fish in the sampled reach

K= Total number of fish captured in the four electrofishing passes

k= Number of marked fish recaptured in the four electrofishing passes

n= Total number of fish marked

SE = Standard Error of $N_{est}$

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